

# CERES Ed3-β2 Cloud Algorithm Status & Validation

**P. Minnis**

*NASA Langley Research Center*

**S. Sun-Mack, Q. Trepte, Y. Chen, S. Gibson, R. Smith, R. Brown, E. Heckert, R. Arduini, Y. Yi, R. Palikonda, D. Spangenberg, C. Yost**

*SSAI*

**F-L. Chang**

*NIA*

**P. W. Heck**

*CIMSS, U. Wisconsin*

*CERES STM November 3-5, 2009*



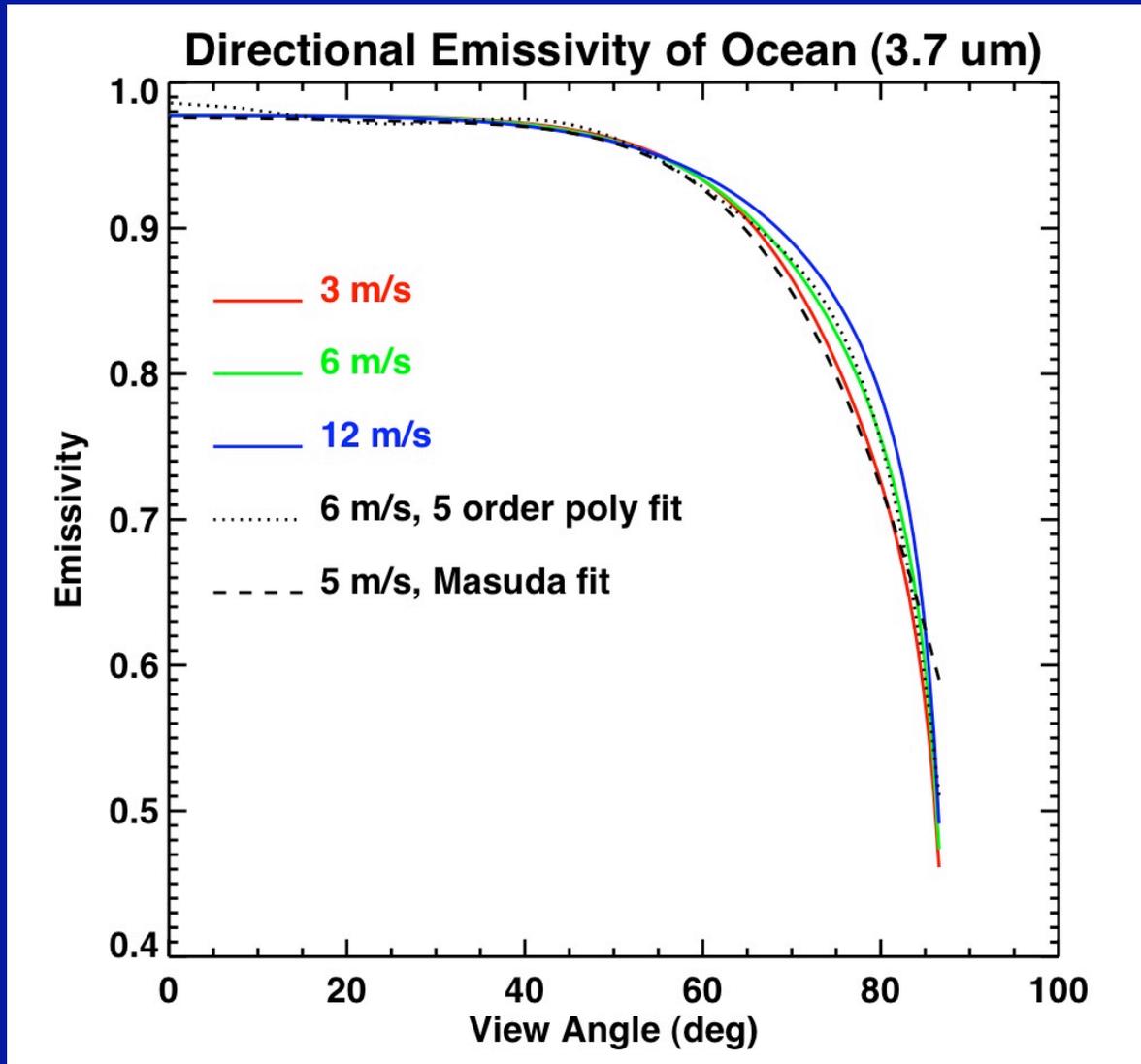
# CERES Ed3 $\beta$ 2 Cloud Mask Changes since May 2009 STM

## Highlights:

1. Further increased daytime ocean cumulus cloud detection
2. Jin's ocean models replaced old emissivity & reflectance models
  - Adjusted thresholds to improve detection
3. Tested MODIS land emissivities, no apparent help
4. Increased daytime polar thin Ci detection over snow using 1.38  $\mu\text{m}$ .
5. Reduced nighttime false clouds over desert, they are dust
6. Fixed the SH ocean 50°S - 60°S negative cloud anomalies
7. Fixed discontinuity in clear sky 3.7-11 over polar transition regions
8. Changed cloud tests for polar night ice cap back to Aqua AEd1 version (based on ADM group's suggestions)
9. Terra 3.8- $\mu\text{m}$  calibration adjusted to match Aqua
  - daytime or  $T > 255\text{K}$ ,  $T_{\text{new}} = T_{\text{old}} - 0.55\text{K}$
  - night and  $T \leq 255\text{K}$ ,  $T_{\text{new}} = f(T_{\text{old}})$



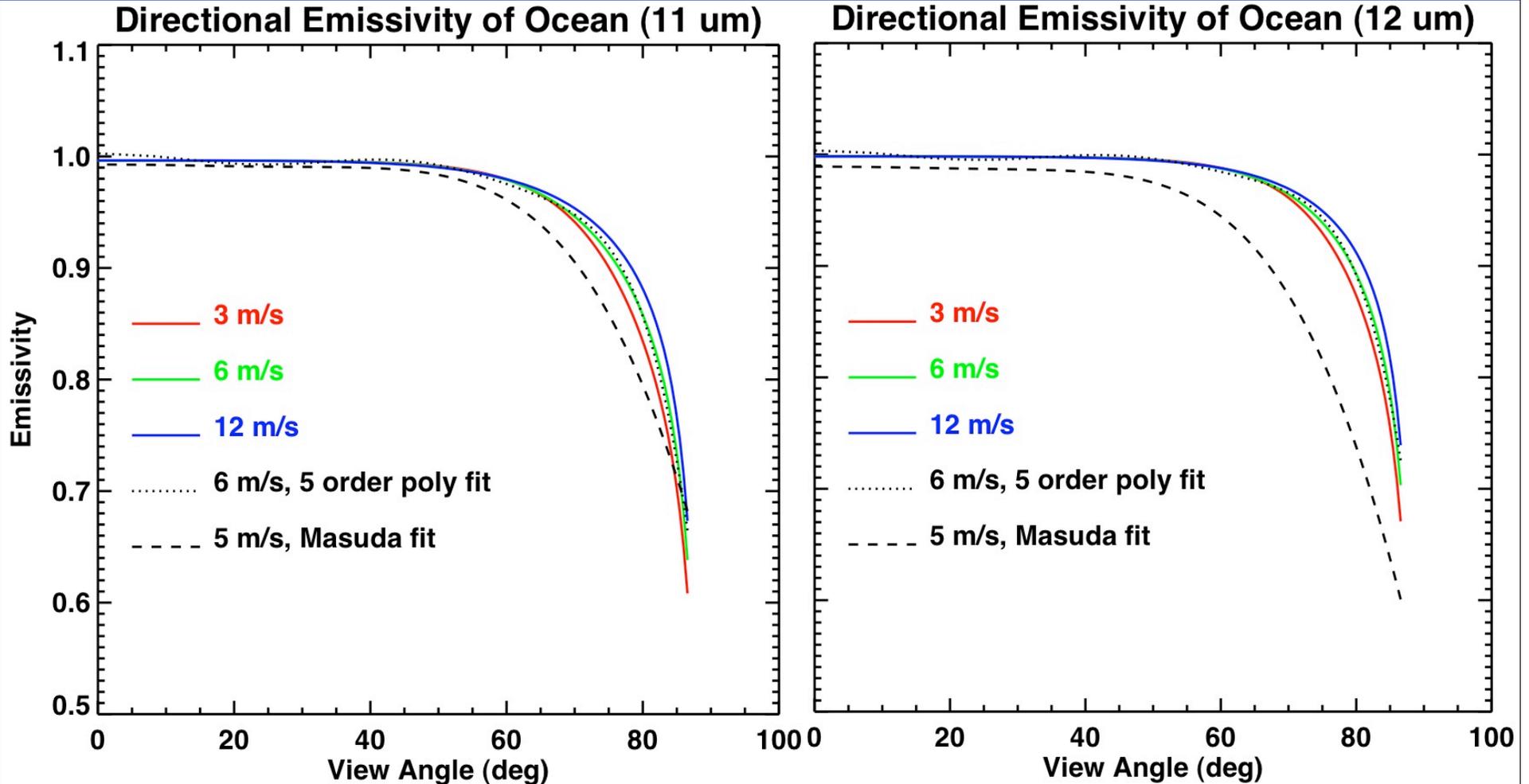
# New Emissivity Models von Zhonghai Jin



New emissivities are  
wind-speed dependent

- less angular change  
with increasing wind

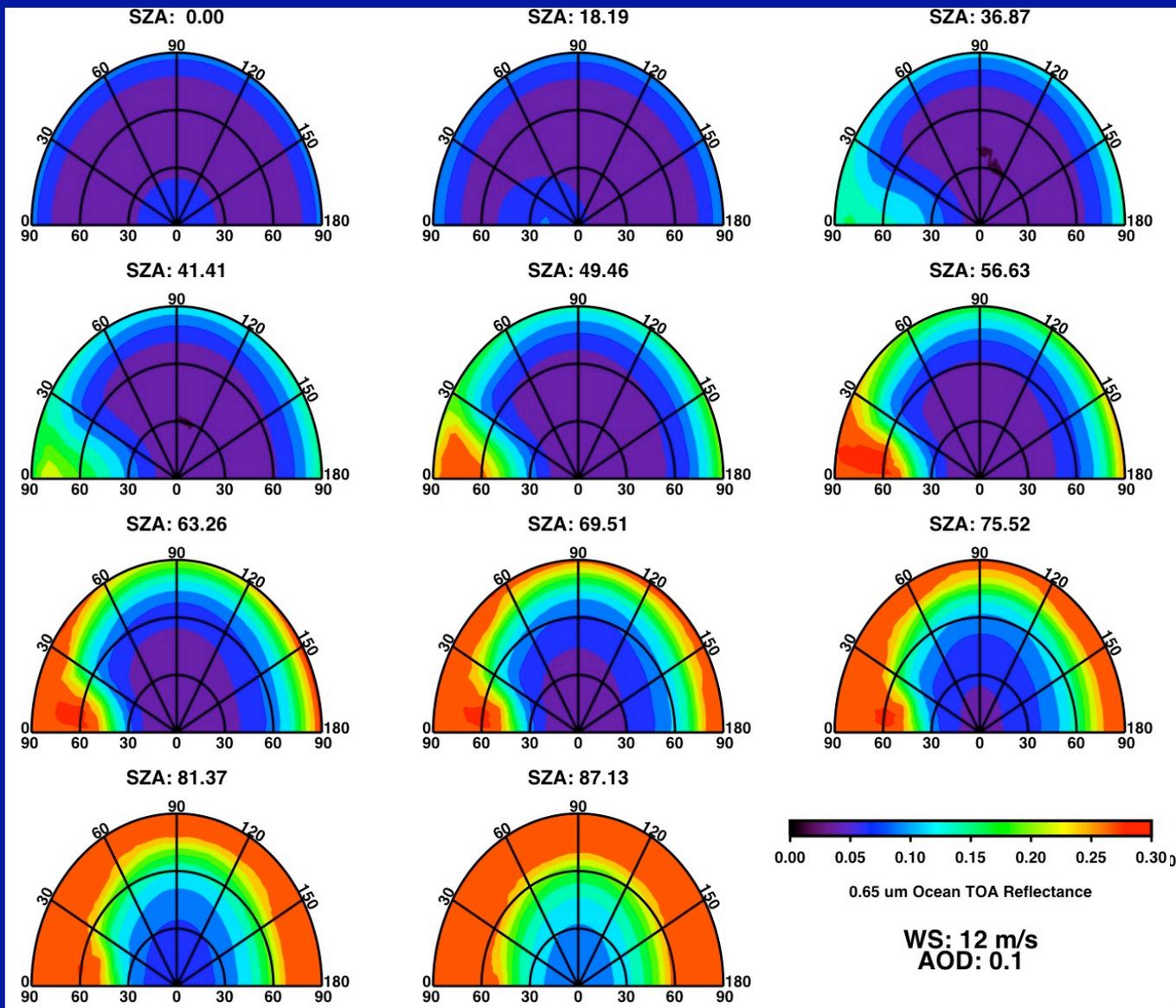
# New Emissivity Models von Zonghai Jin



New emissivities are wind-speed dependent

- less angular change with increasing wind & wavelength

# 0.65 $\mu\text{m}$ TOA Ocean Reflectance

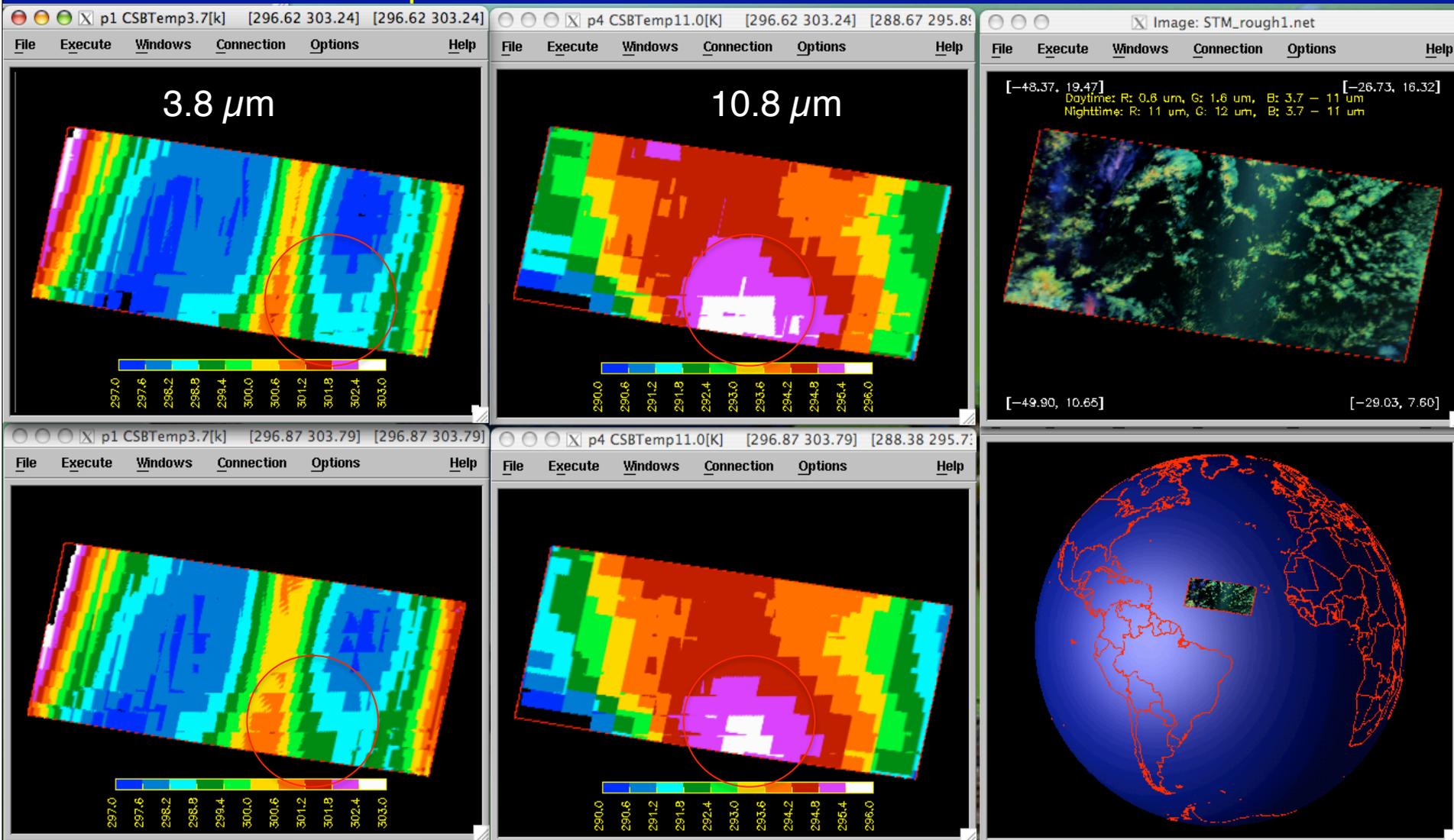


- 3.8- $\mu\text{m}$  reflectance model also used

# SIR & IR Clear-sky Temperatures, Terra, 20070605

Top: w/ Jin model

Bottom: old model

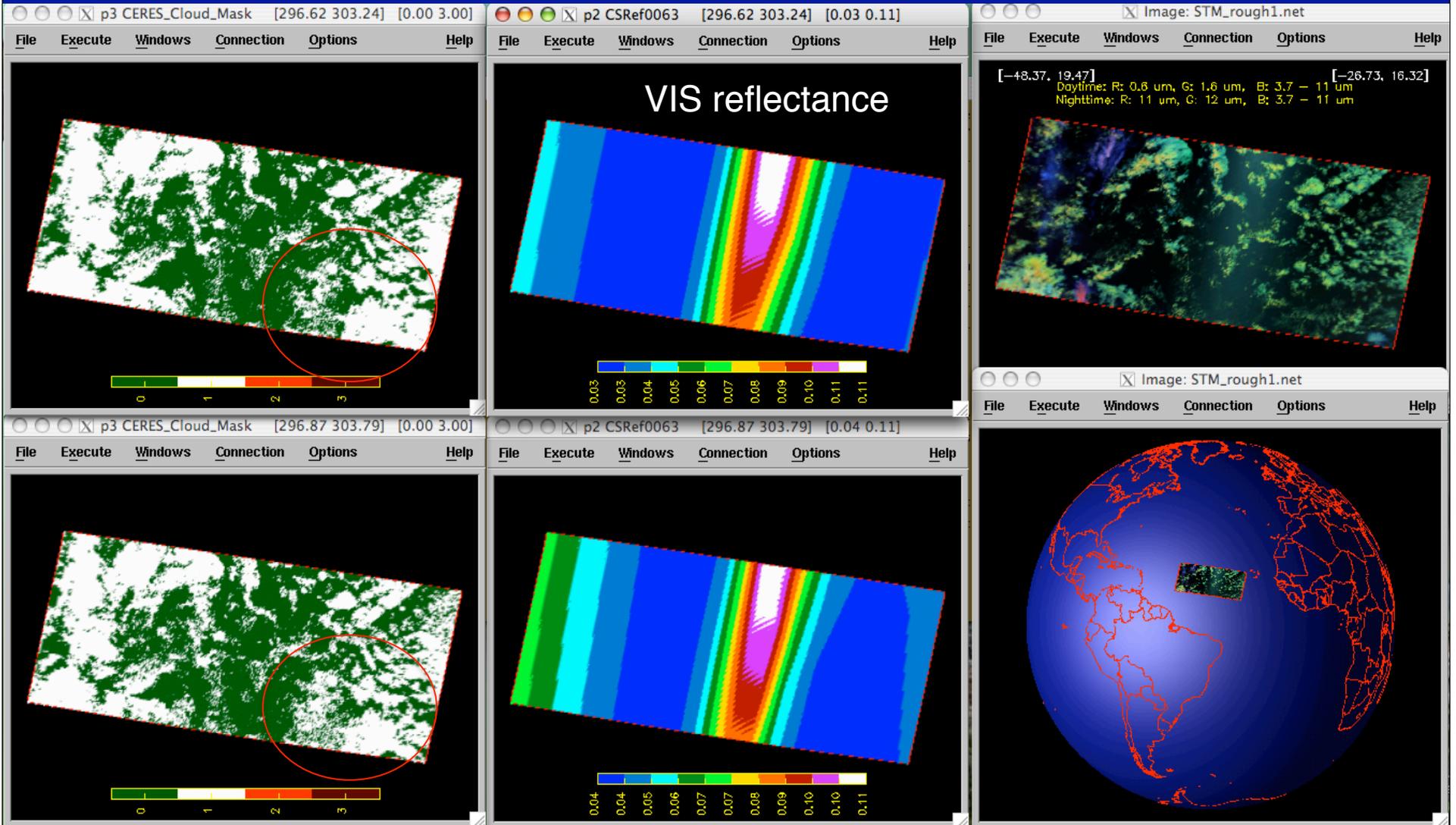


Temps running higher for all 10.8  $\mu\text{m}$ , lower for 3.9  $\mu\text{m}$

# VIS Reflectance Mask, Terra, 20070605

Top: w/ Jin model

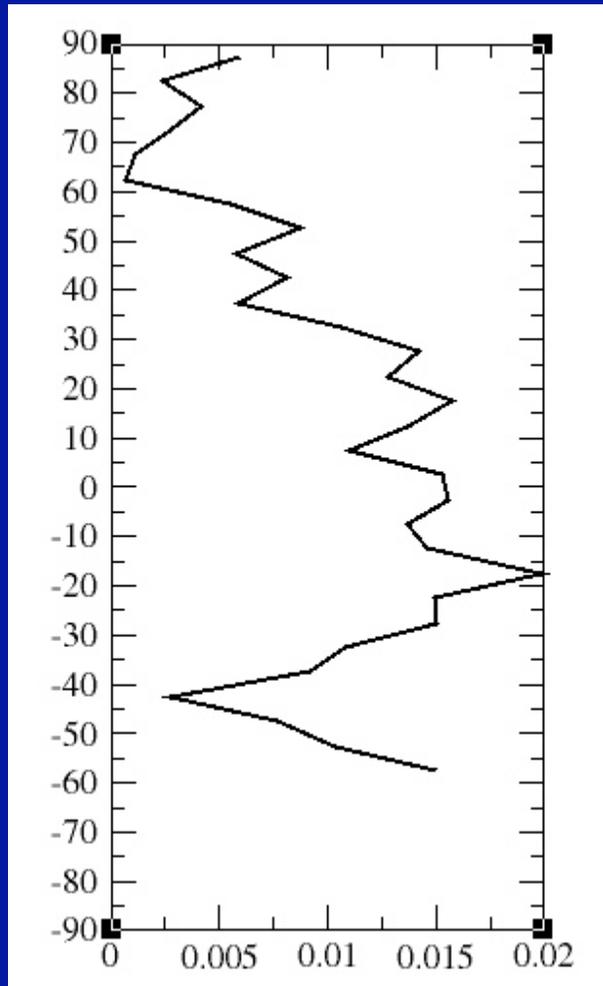
Bottom: old model



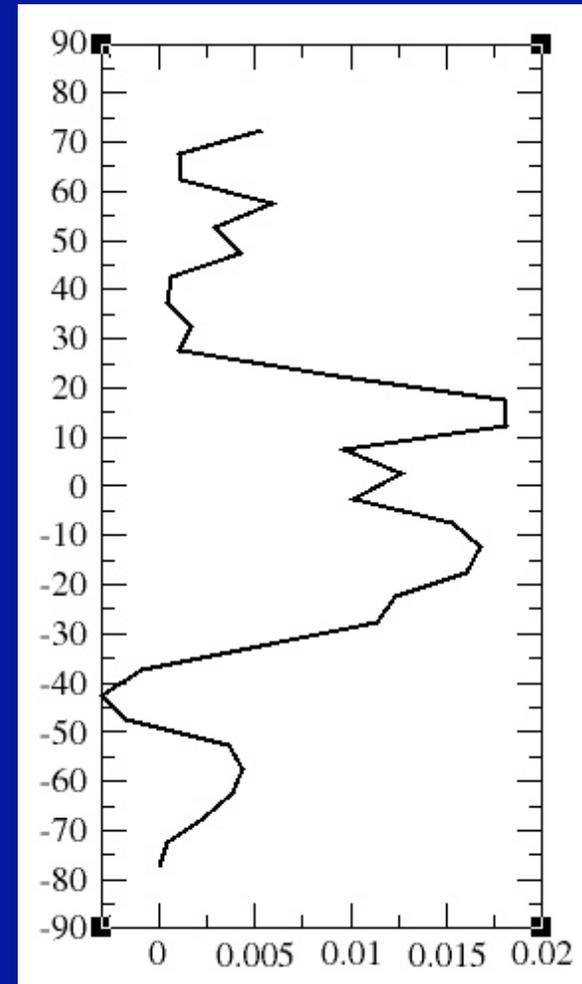
New model has less variability across angles, detects more clouds

## Impact of Jin models on cloud mask, Terra, 20070605

day



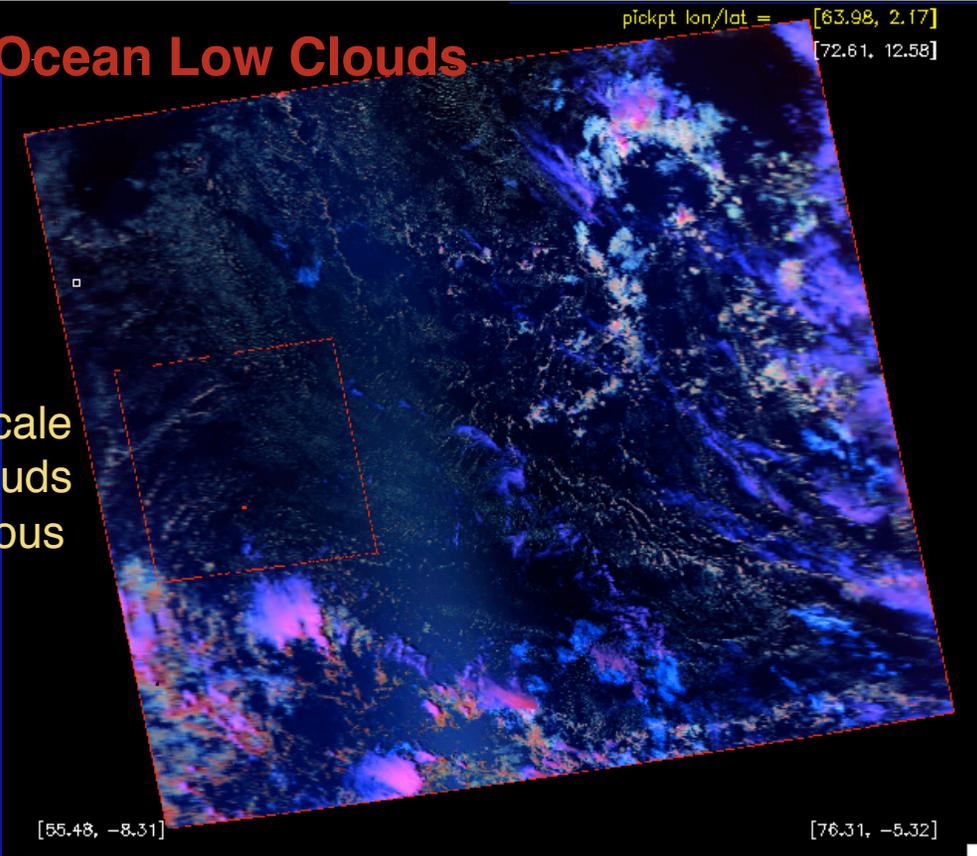
night



Cloud fraction increases by ~1% during day, 0.75% at night

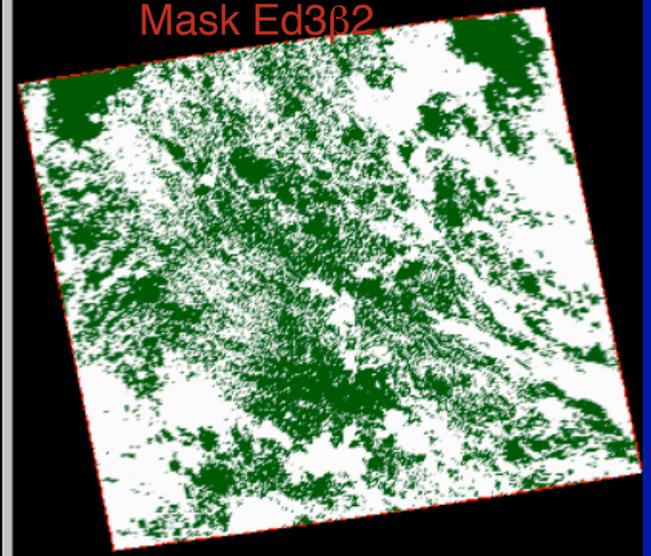
# Daytime Ocean Low Clouds

Many sub-scale or subtle clouds are not obvious in RGB.

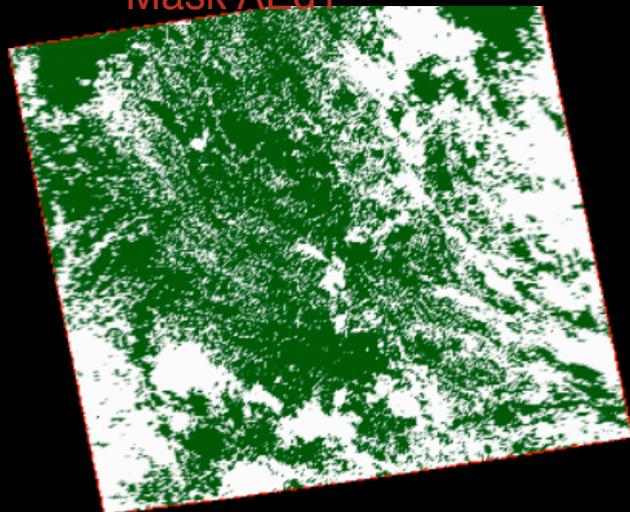


Aqua MODIS  
20071225, UTC 0915

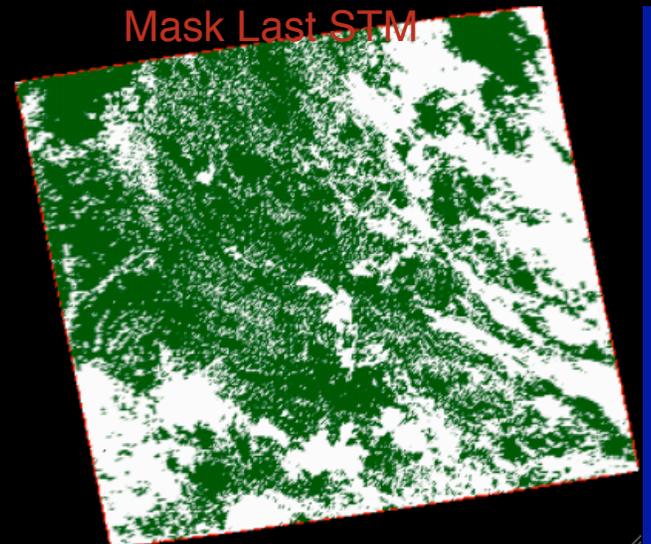
Mask Ed3β2



Mask AEd1

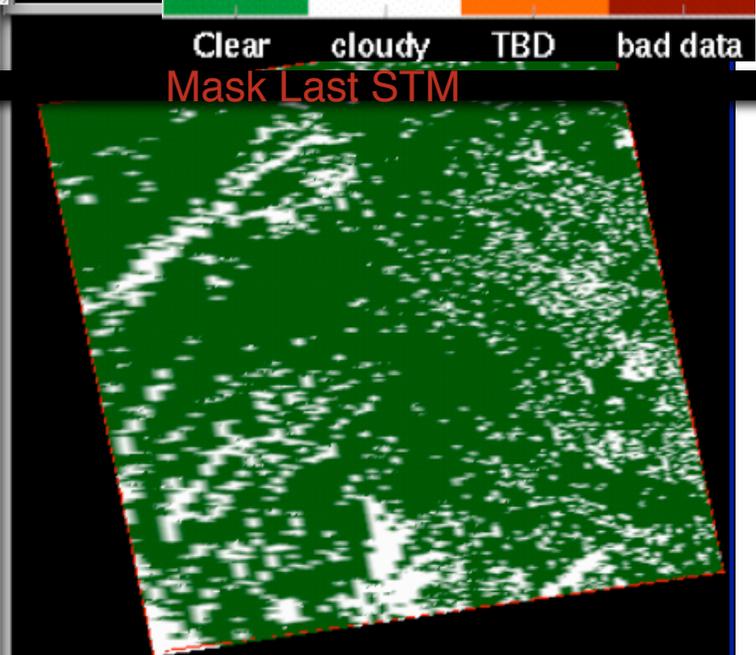
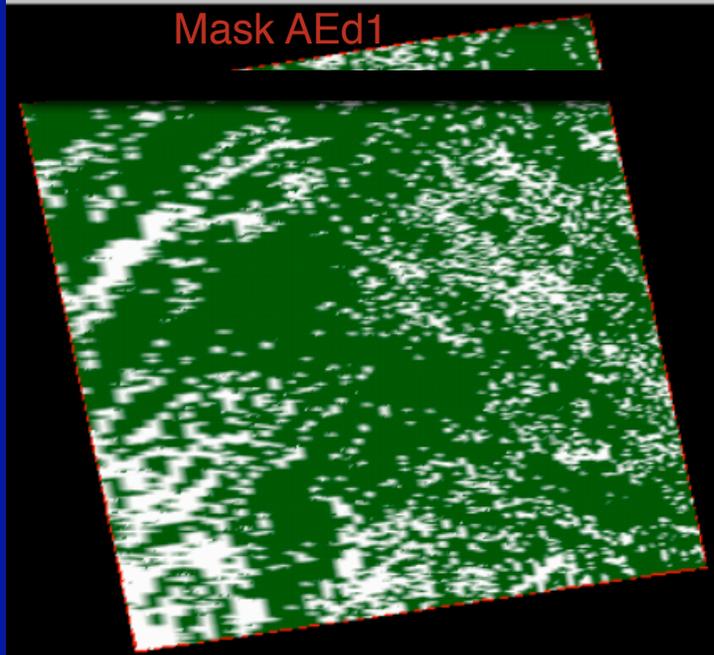
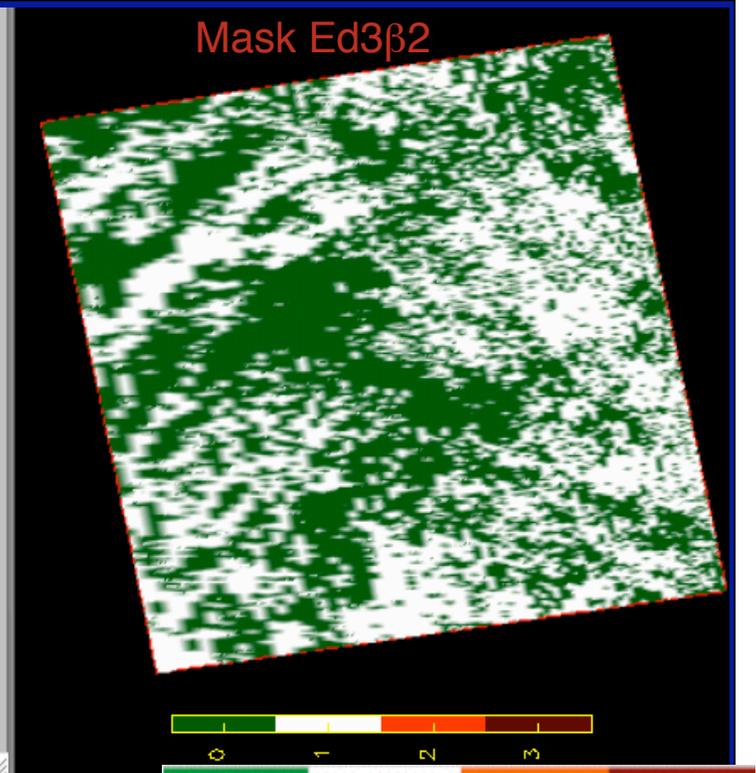
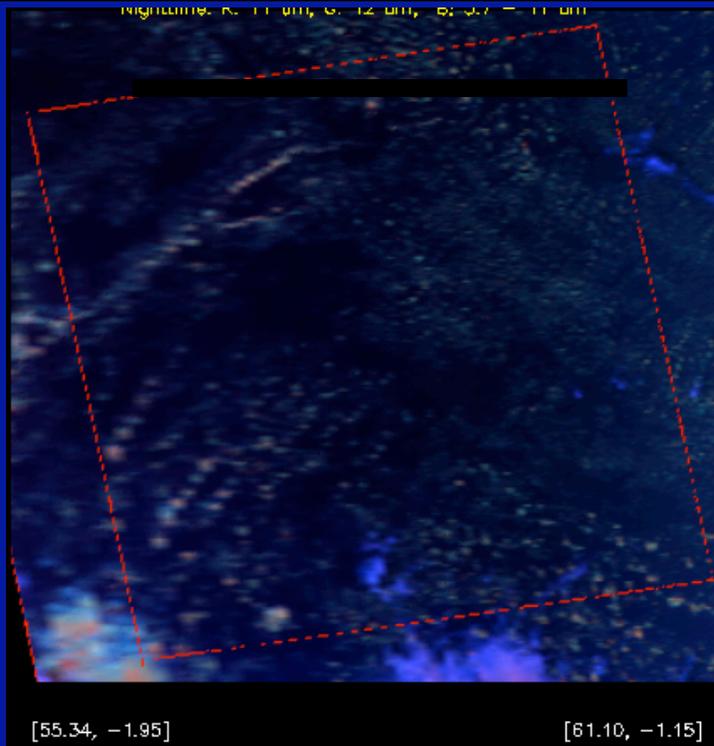


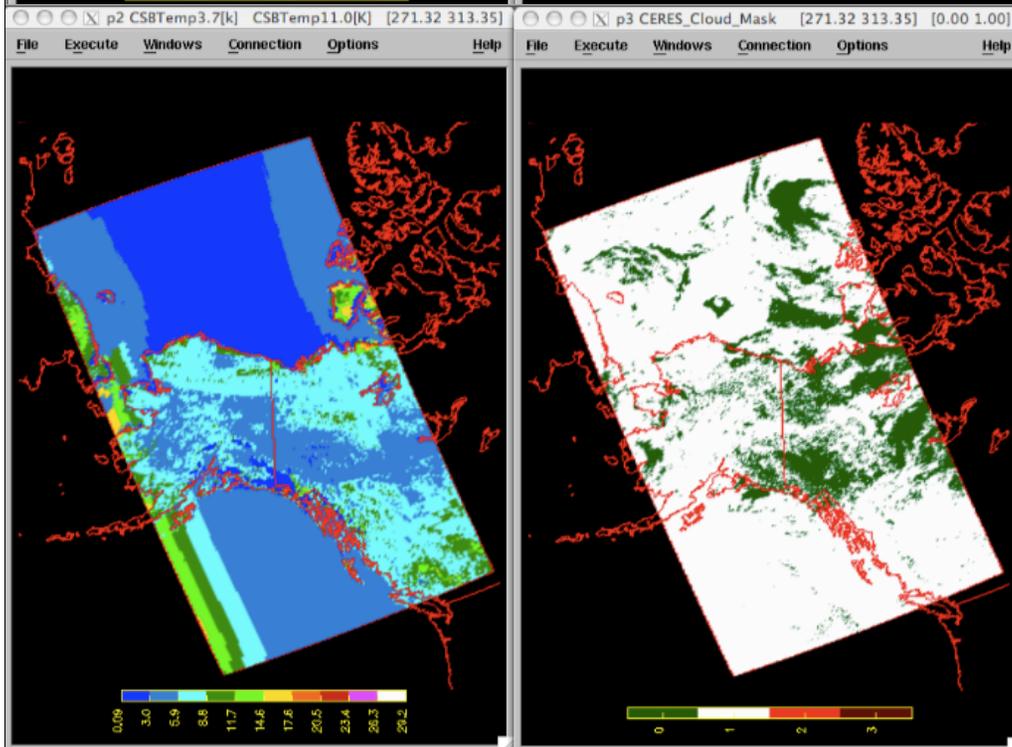
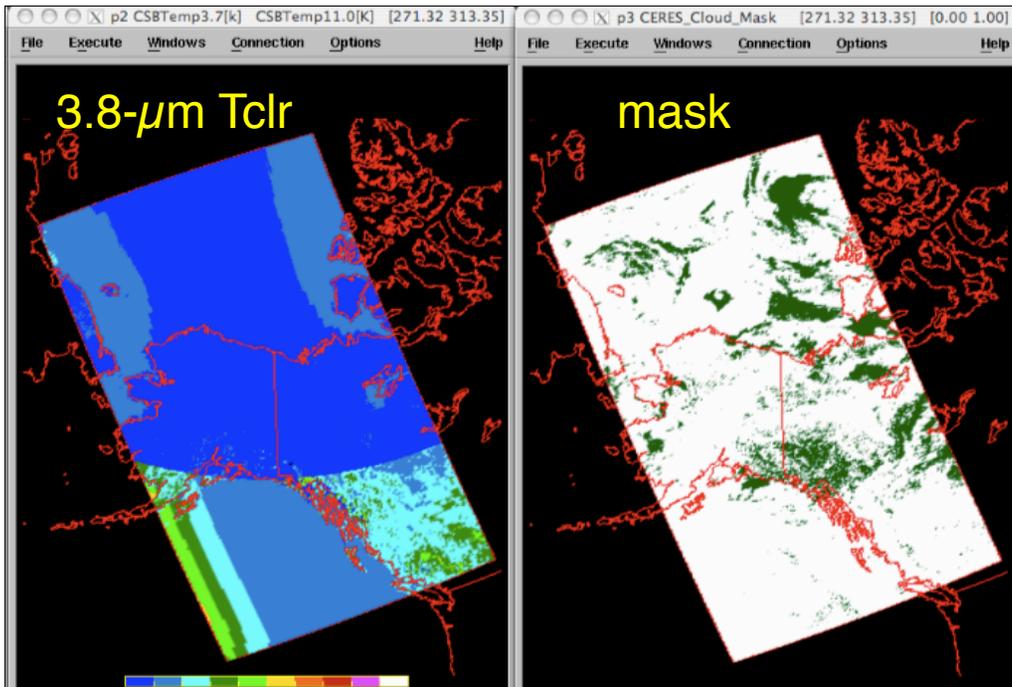
Mask Last STM



Aqua MODIS  
20071225, UTC 0915

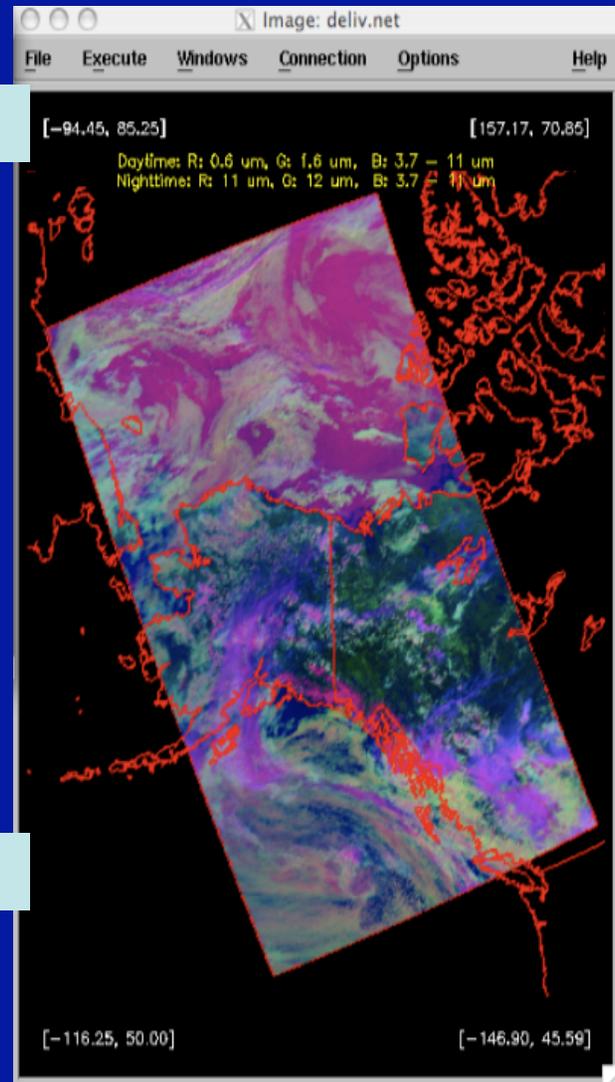
zoomed  
from last  
page





# Polar Transition Fix

Before fix

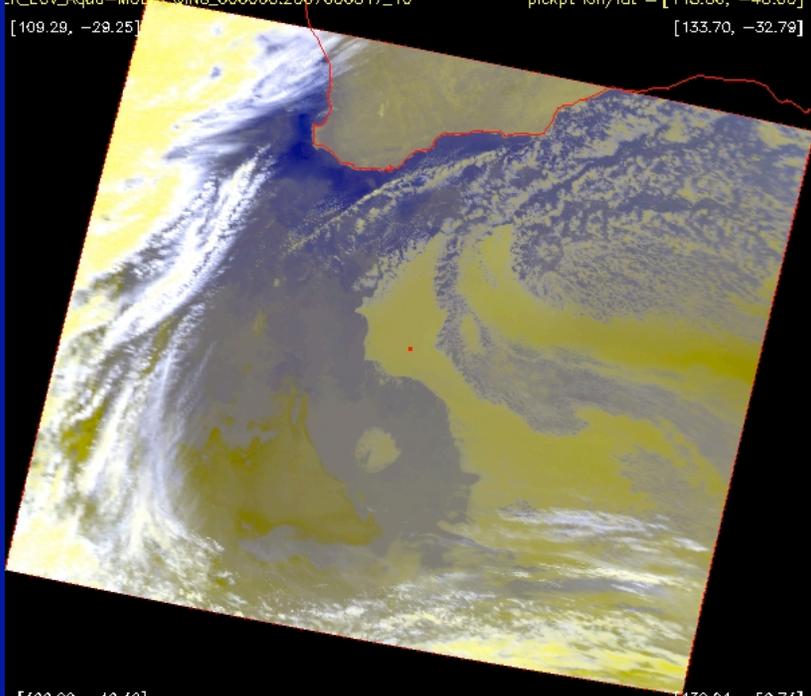


After fix

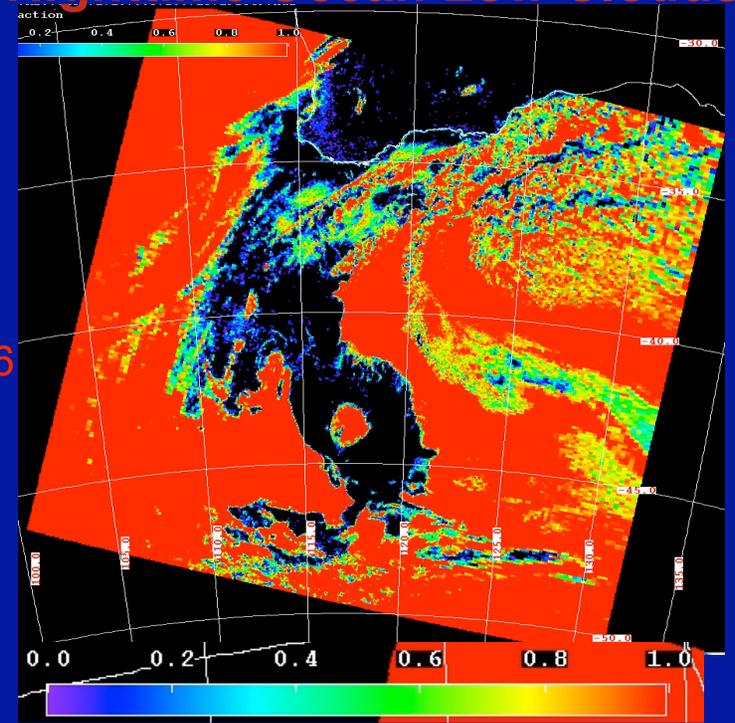
# Aqua MODIS 20070605, UTC 1710

ER\_ECV\_Aqua-MODIS\_QING\_000000.2007060517\_10  
[109.29, -29.25]

pickpt lon/lat = [118.66, -40.60]  
[133.70, -32.79]



# Nighttime Ocean Low Clouds

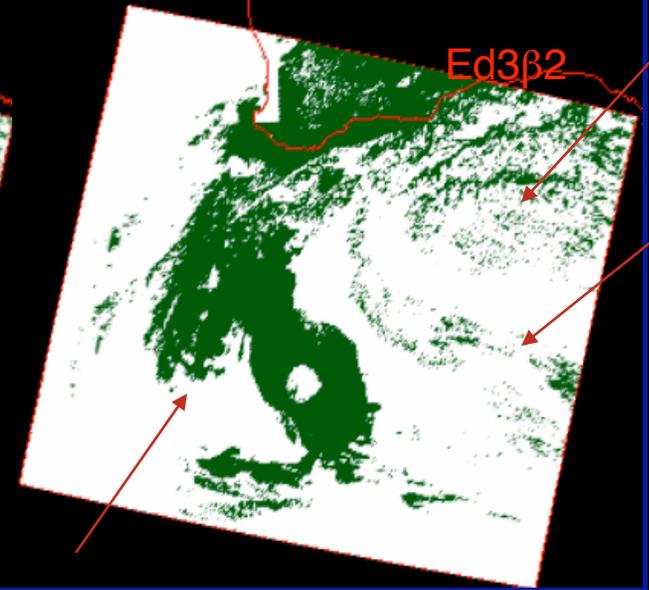
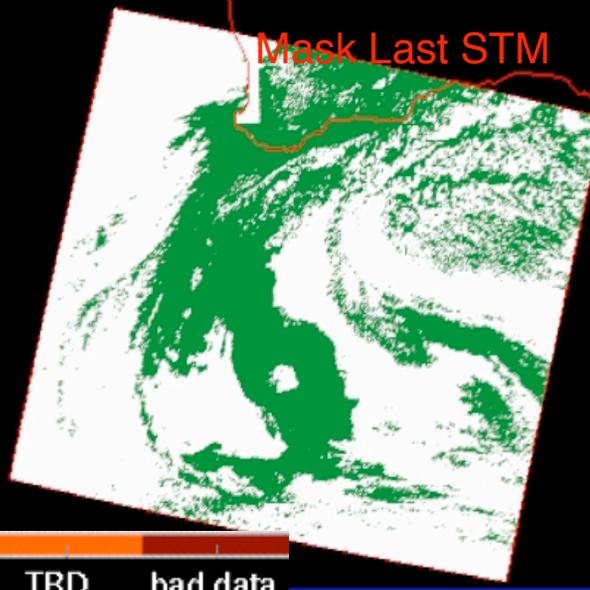
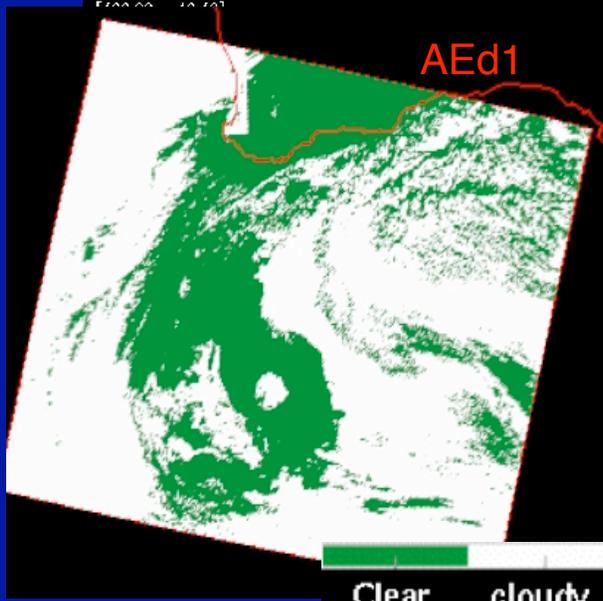


MYD06

AEd1

Mask Last STM

Ed3β2

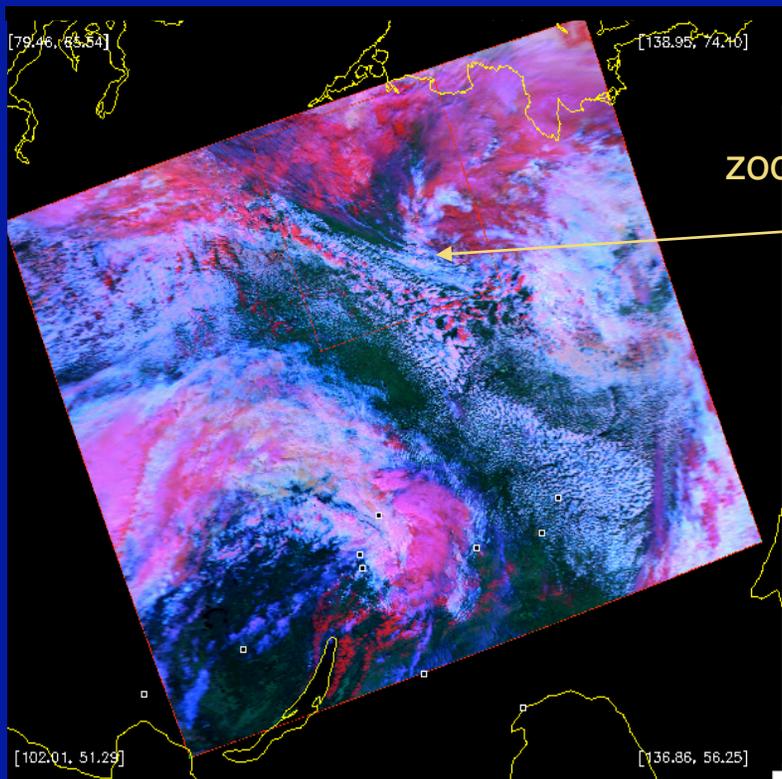


Clear cloudy TBD bad data

more low clouds

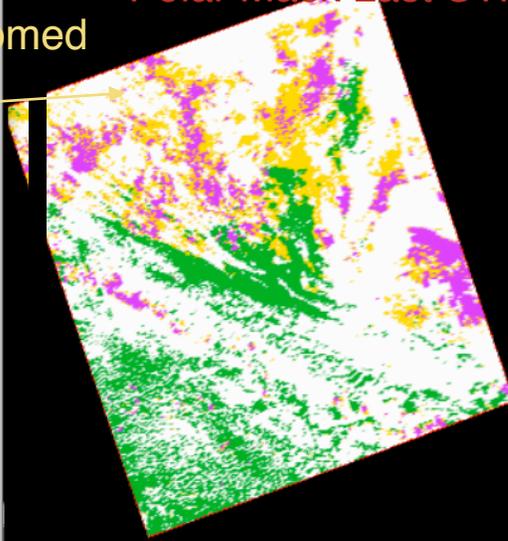
# Daytime Polar, detect more thin Ci over snow/ice

Aqua MODIS  
June 5, 2007, 0450 UTC

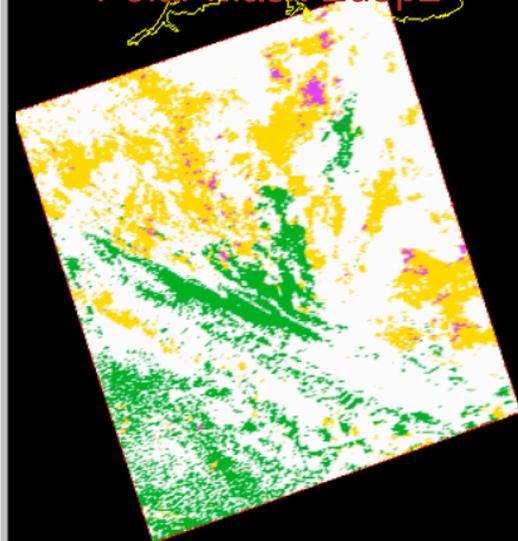


zoomed

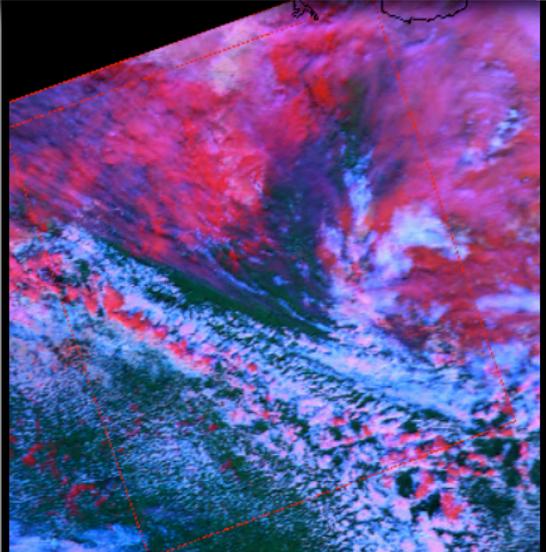
Polar Mask Last STM



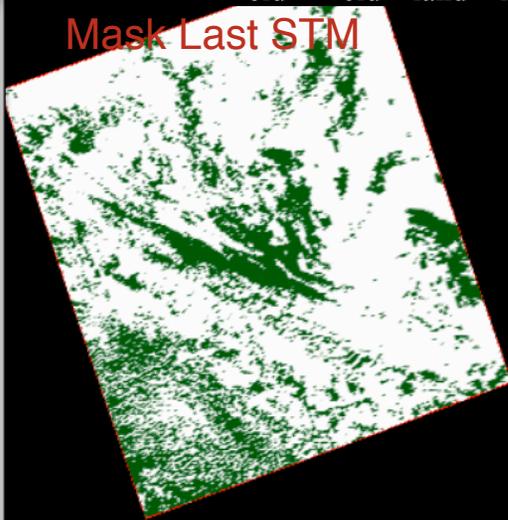
Polar Mask Ed3β2



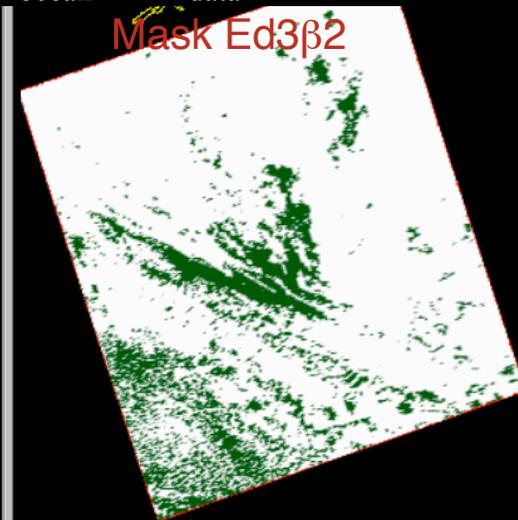
strong weak clear snow clear TBD bad  
cld cld land ice ocean data



Mask Last STM



Mask Ed3β2



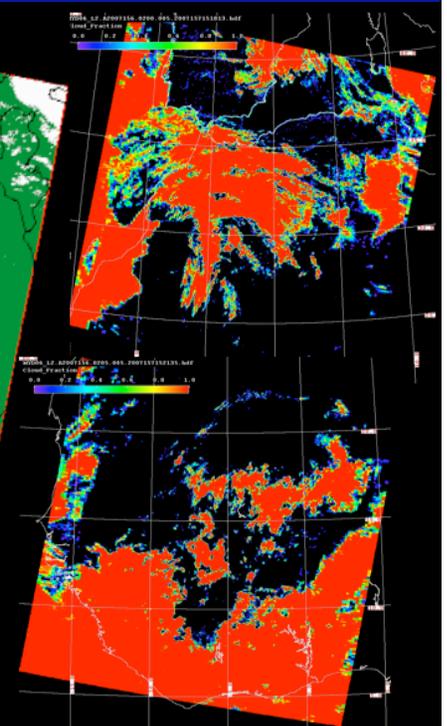
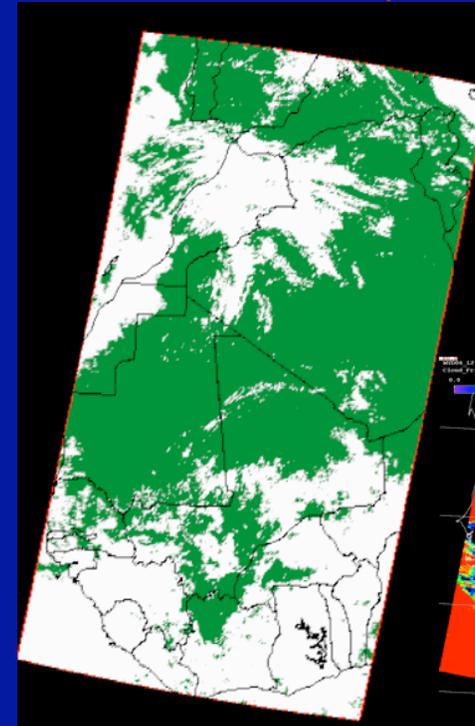
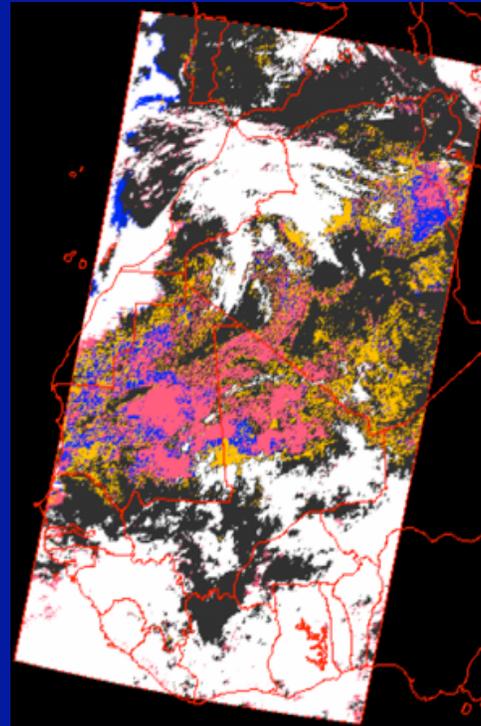
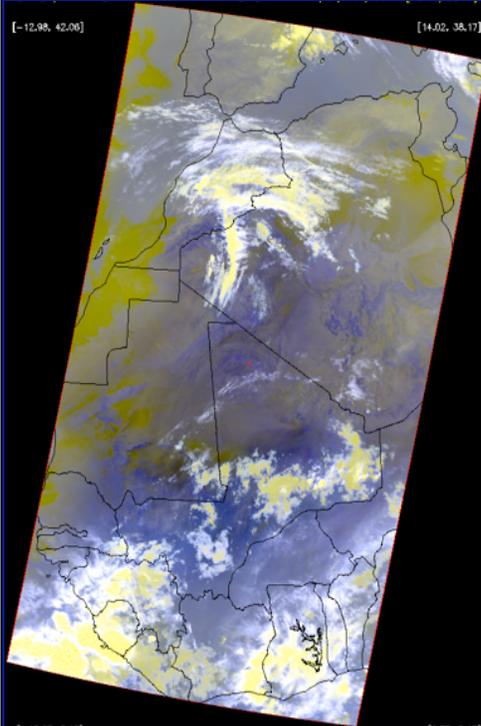
# Nighttime Desert Reduced false low clouds (dust)

Aqua MODIS  
June 5, 2007, 0200-0205 UTC

Cloud Category  
Last STM

Mask Ed3β2

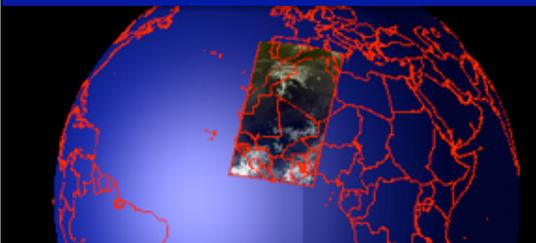
MYD06



good weak glint VIST else

Clear cloudy TBD bad data

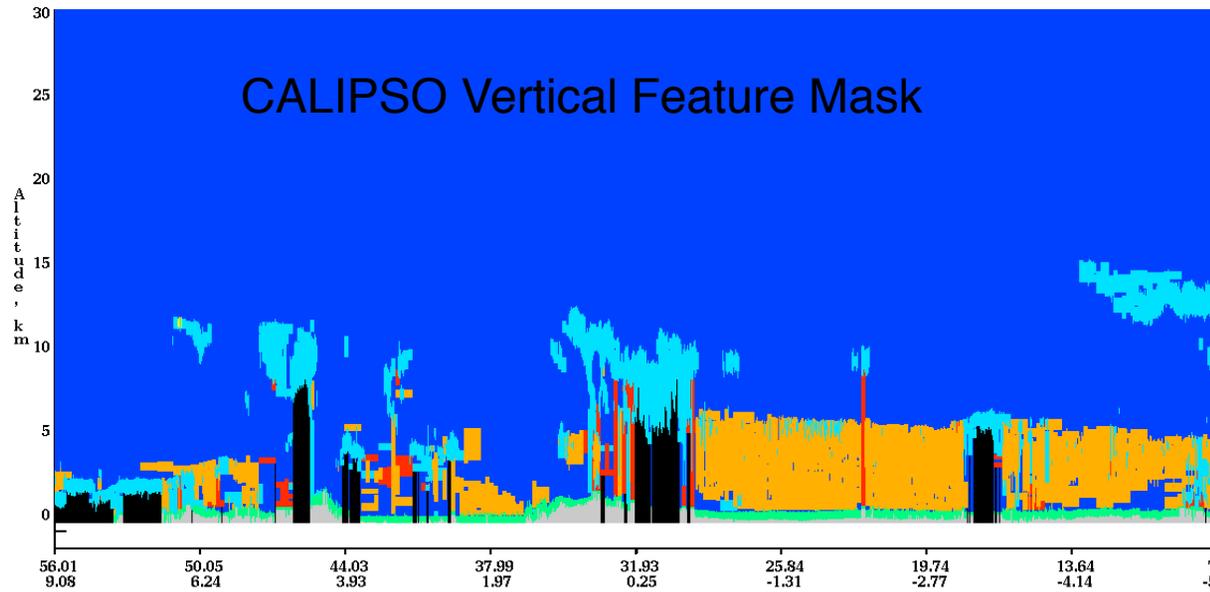
Dust clouds minimized at night



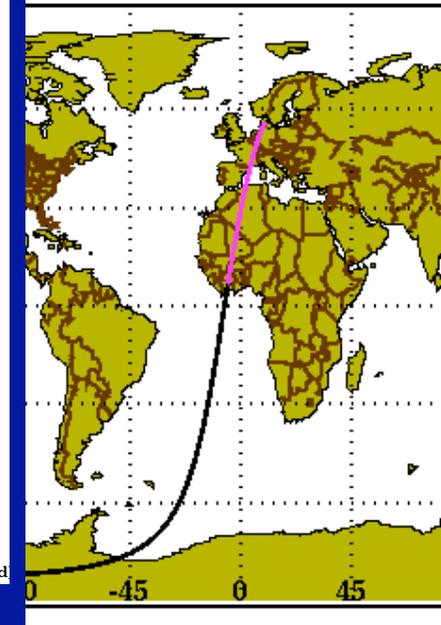
Vertical Feature Mask Begin UTC: 2007-06-05 01:57:05.4692 End UTC: 2007-06-05 02:10:34.8601

Version: 2.01 Image Date: 02/22/2008

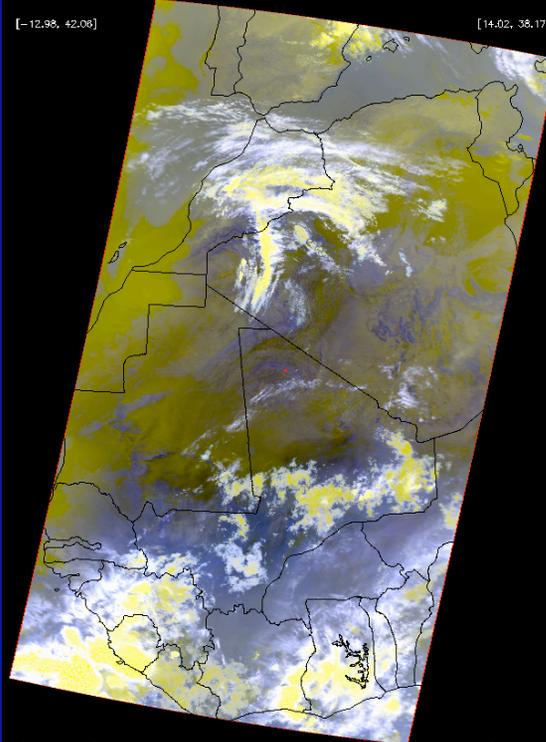
# CALIPSO Vertical Feature Mask



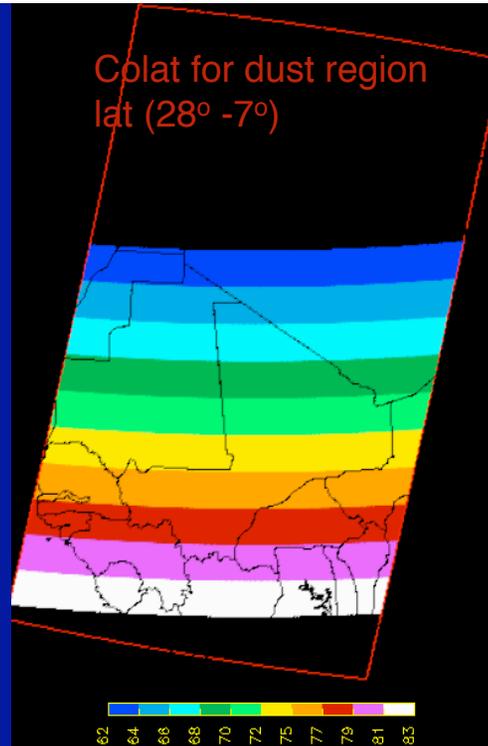
05 01-57-05 UTC Nighttime Co  
rsion: 2.01 Image Date: 02/21/2



Feature ECV\_Aqu-MODIS\_QINGD\_000000.2007060502\_00\_05 plekpt lon/lat = [-3.98, 22.85] aerosol, 4 = stratospheric feature, 5 = surface, 6 = subsurface, 7 = no signal (total attenuated)



Cpllat for dust region  
lat (28° -7°)



Most gray dirty brown stuff in RGB is classified as aerosol in VFM.

Formerly called clouds because of very negative T3.7-T11.

# Zonal Cloud Fraction Differences Compared with AEd1

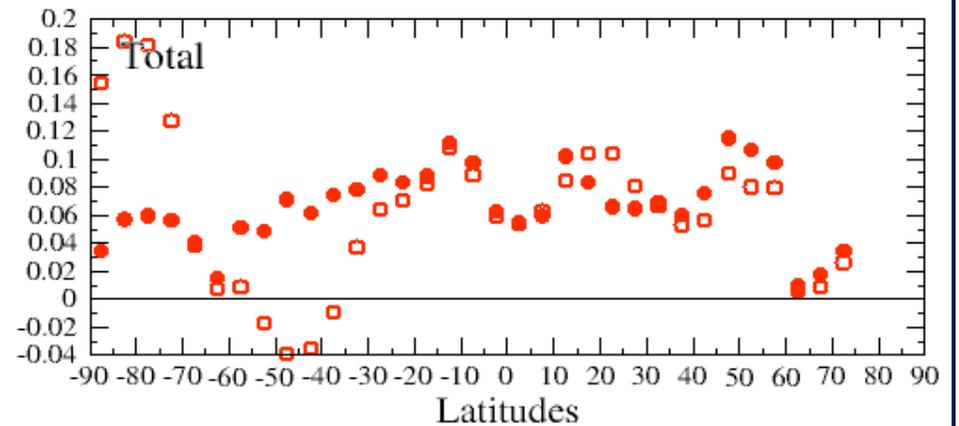
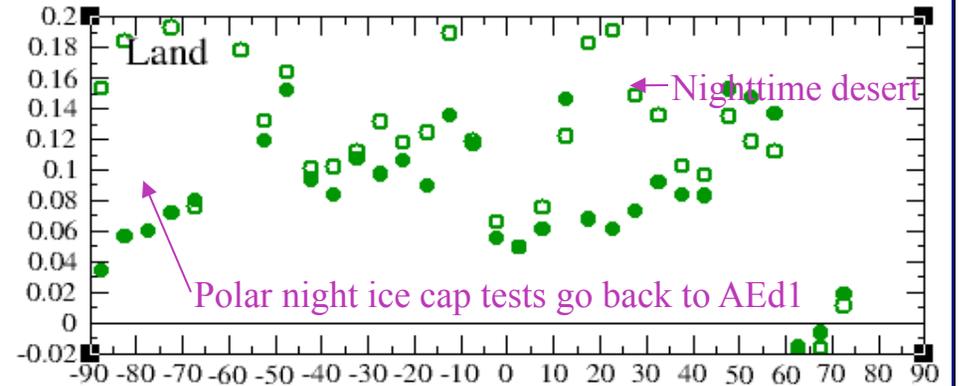
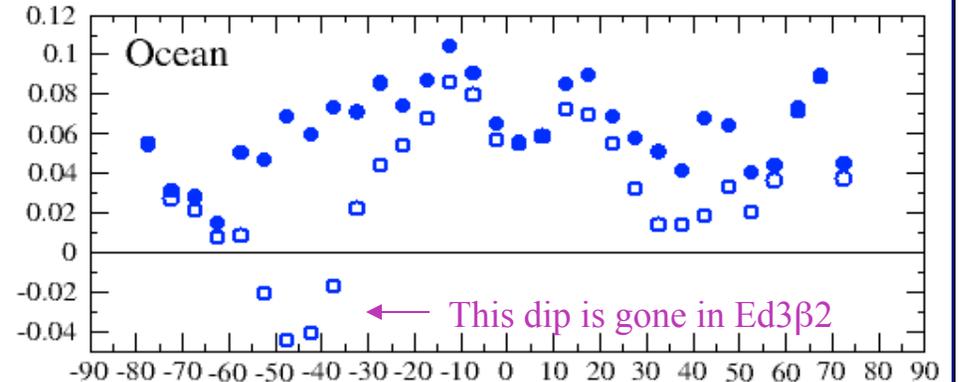
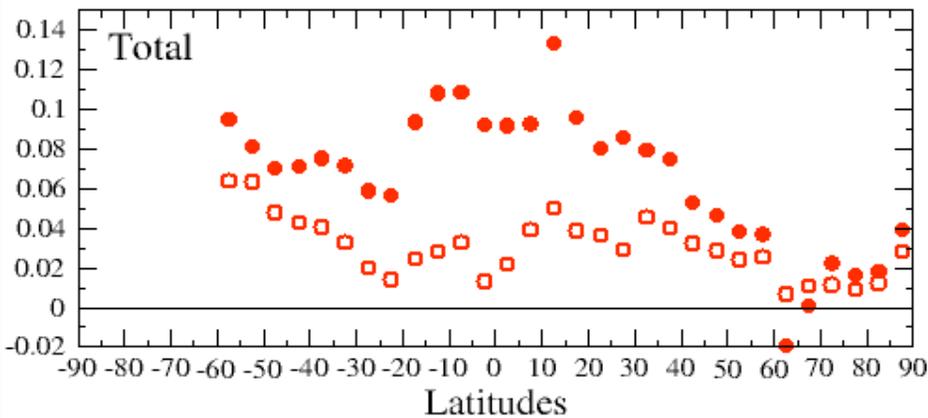
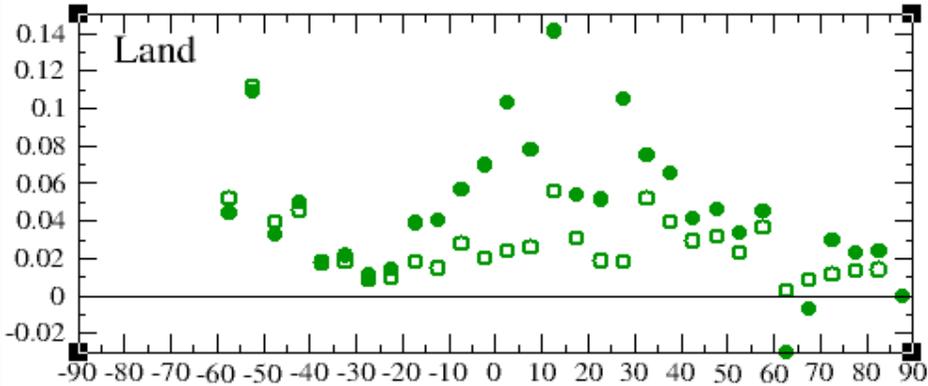
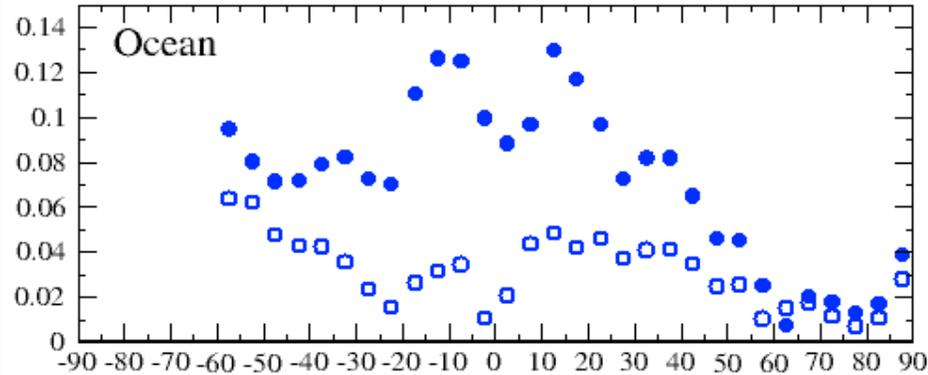
○ Ed3 $\beta$ 2 - AEd1

◻ Last STM - AEd1

Aqua 20070605

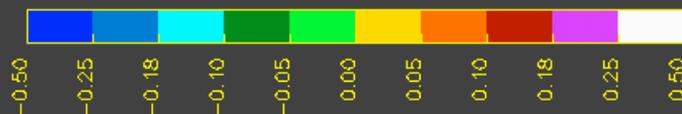
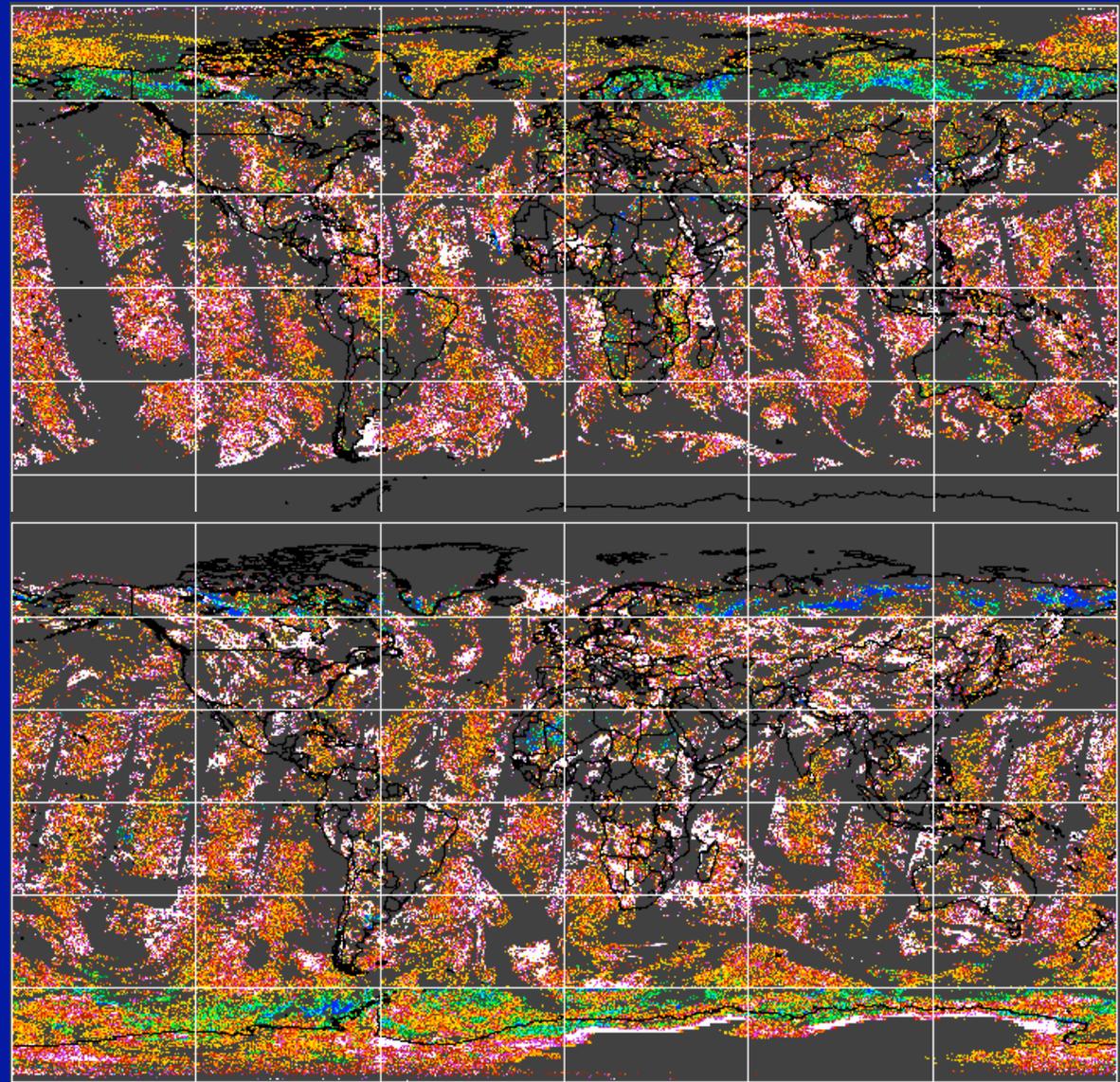
Daytime

Nighttime



# Cloud Fraction differences between Ed3 $\beta 2$ and Aqua Ed1 Aqua 20070605

- Ocean clouds increased (day and night)
- NH polar transition area false clouds reduced, smoothed discontinuity (it was due to CS 3.7-11)
- Polar night super cold ice cap tests go back to Aqua Ed1 (ADM group's suggestion), so no diffs



## Comparison of CERES Cloud Fraction with CALIPSO V2 VFM 20060715

	Daytime Arctic (73101)	Daytime Non-polar Ocean (129380)	Daytime Non-polar Land (55384)	Nighttime Non-polar Ocean (155006)	Nighttime Non-polar Land (54567)	Nighttime Antarctica (99702) <i>(back to AEd1)</i>
CALIPSO-Cloudy CERES-Cloudy	71.7% <i>72.6%</i>	64.16% <i>66.57%</i>	44.75% <i>49%</i>	67.21% <i>67.21%</i>	40.23% <i>40.22%</i>	51.10% <i>48.1%</i>
CALIPSO-Cloudy CERES-Clear	9.26% <i>8.37%</i>	17.82% <i>15.41%</i>	23.44% <i>20.33%</i>	15.15% <i>15.15%</i>	14.77% <i>14.78%</i>	23.96% <i>27.68%</i>
CALIPSO-Clear CERES-Cloudy	4.97% <i>5.2%</i>	1.4% <i>1.8%</i>	1.01% <i>2.8%</i>	2.58% <i>2.58%</i>	7.5% <i>6.47%</i>	8.8% <i>4.16%</i>
CALIPSO-Clear CERES-Clear	14.07% <i>13.8%</i>	16.61% <i>16.17%</i>	29.13% <i>27.87%</i>	15.06% <i>15.06%</i>	37.5% <i>38.53%</i>	15.21% <i>20%</i>
Yes-Yes	85.8% <i>86.4%</i>	80.8% <i>82.7%</i>	73.9% <i>76.9%</i>	82.??	77.7% <i>78.7%</i>	66.3% <i>68.1%</i>

### Last STM Ed3β2

- CALIPSO V2 sometimes misidentify heavy dust as clouds, overestimates low clouds, improvements in V3.
- CERES Ed3β2 uses Ed3β2 mask, but Ed3β1 framework

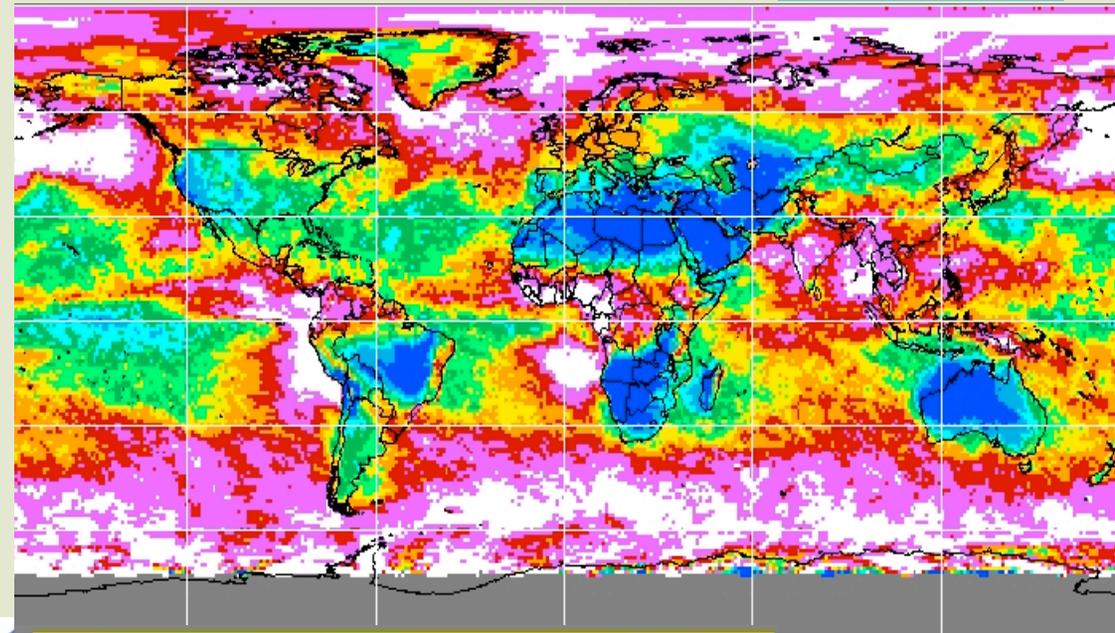
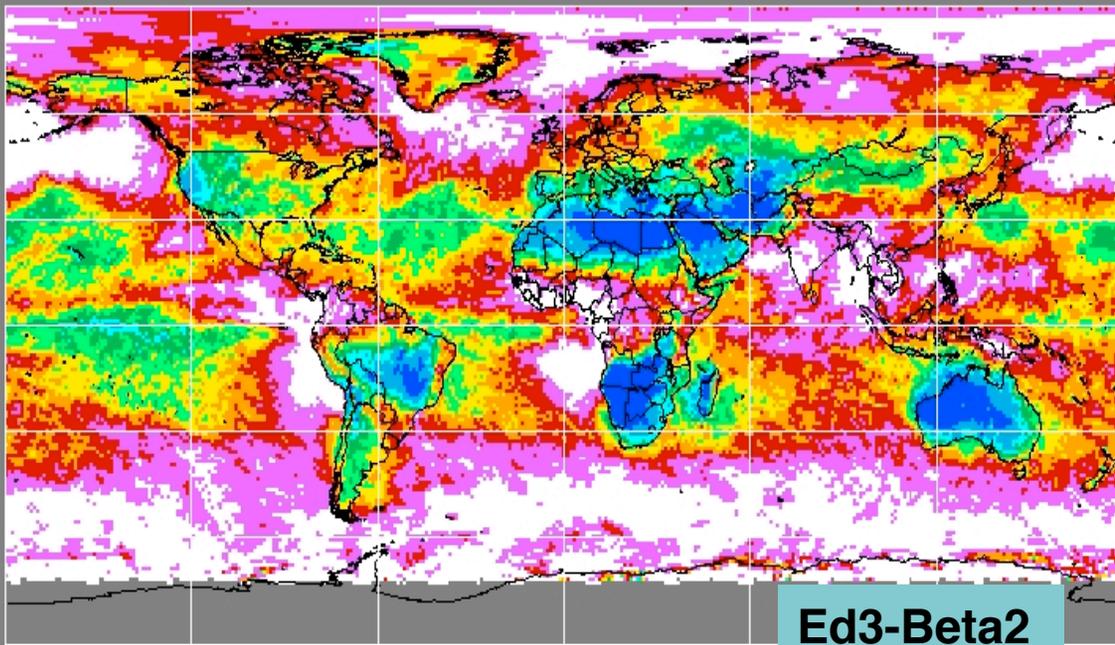
# Cloud Fraction



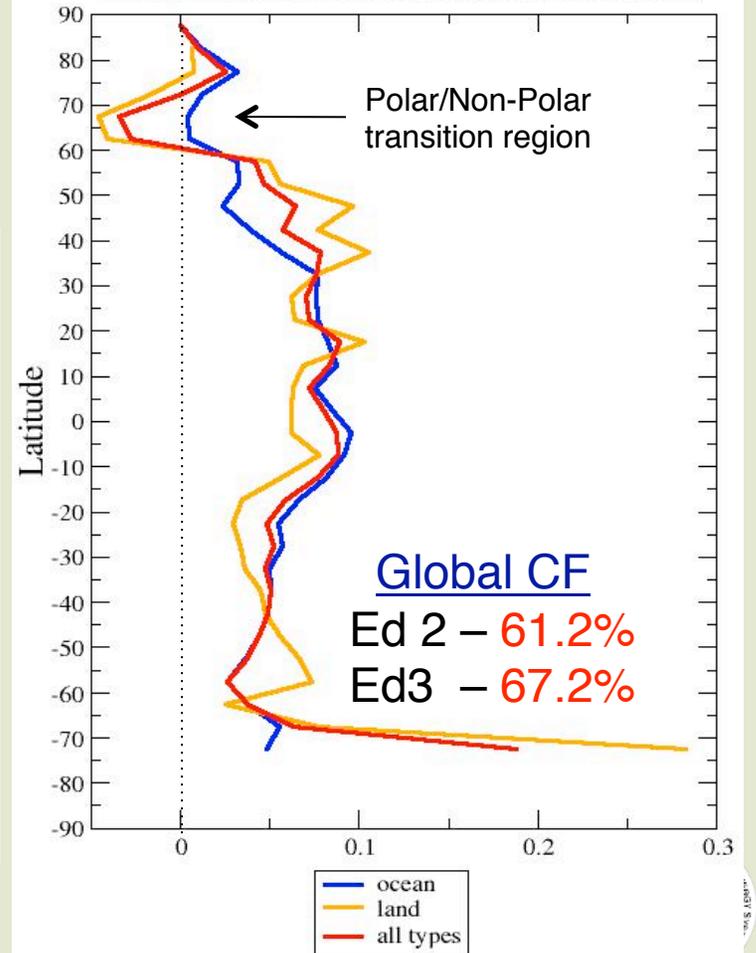
# Terra 200708 Day Time Cloud Fraction

CF Diff (Ed3Beta2-Ed2)

	Ocean	Land
Global:	0.059	0.058
Polar:	0.025	0.022
NonPolar:	0.064	0.062



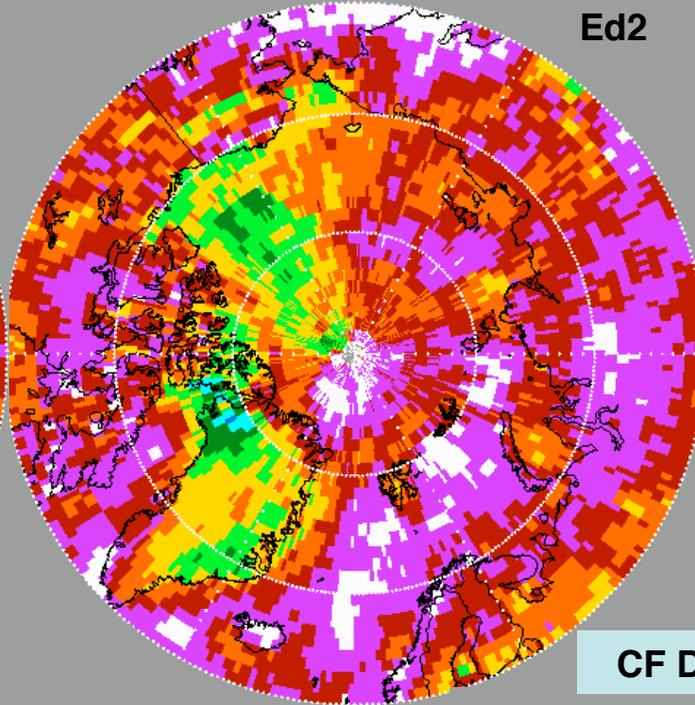
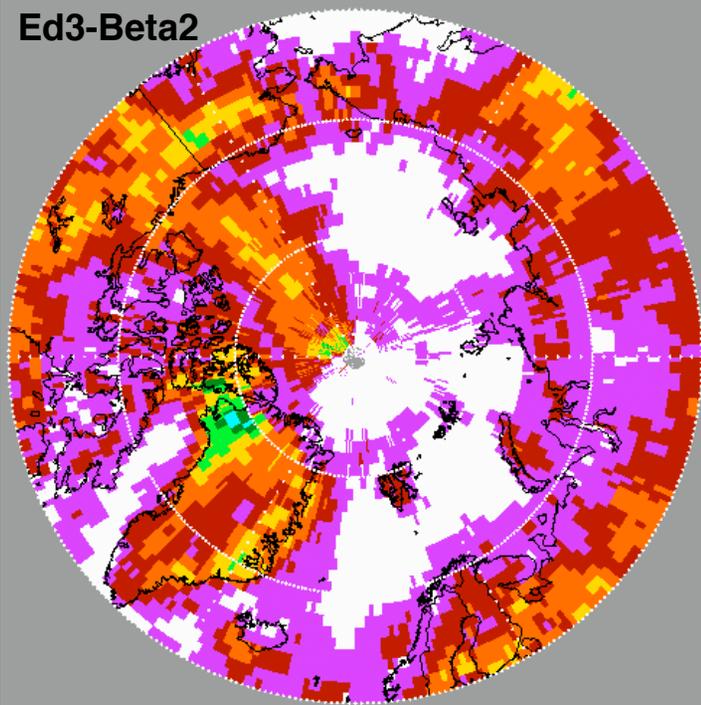
200708 Terra-MODIS Ed3Beta2-Ed2AQC Total Phase Day



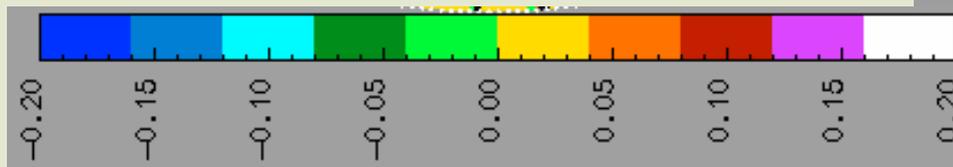
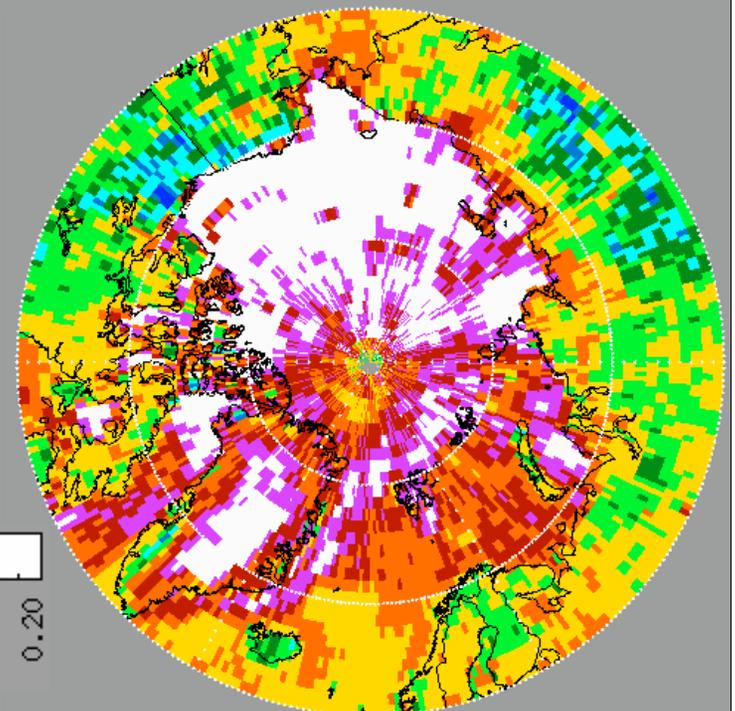
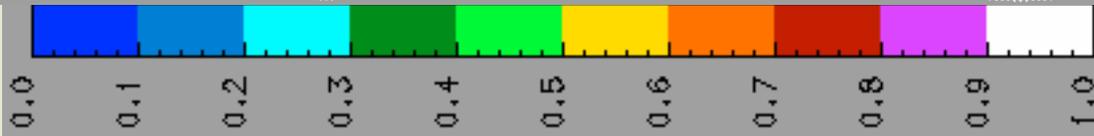
Ed3-Beta2

Ed2

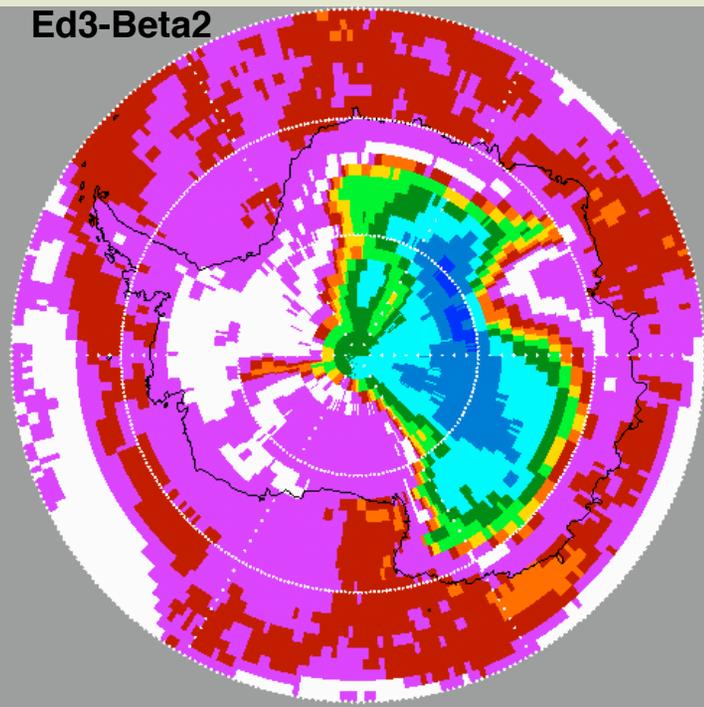
Terra 200708,  
Night Time,  
Cloud Fraction,  
Northern Polar  
Region



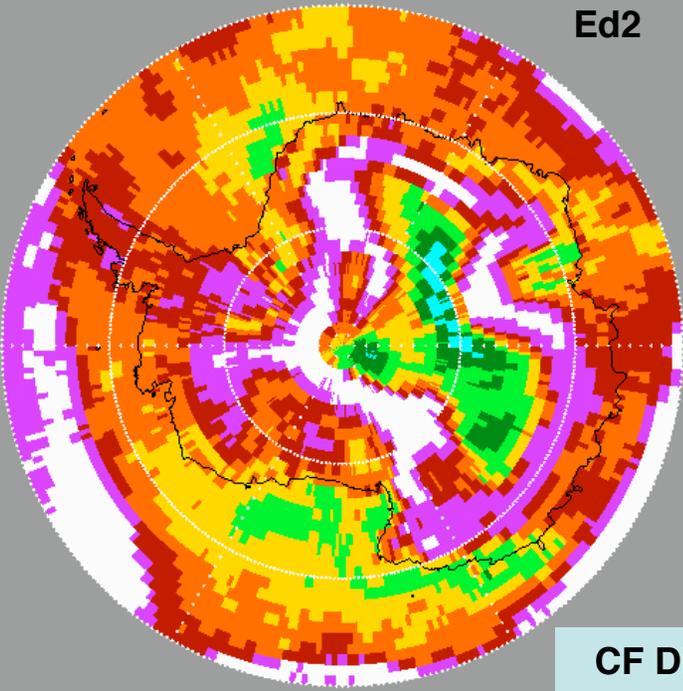
CF Diff (Ed3-Beta2 minus Ed2)



Ed3-Beta2

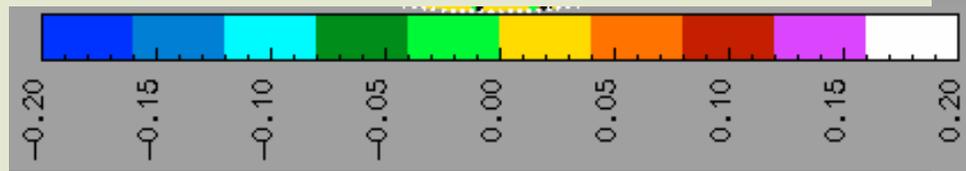
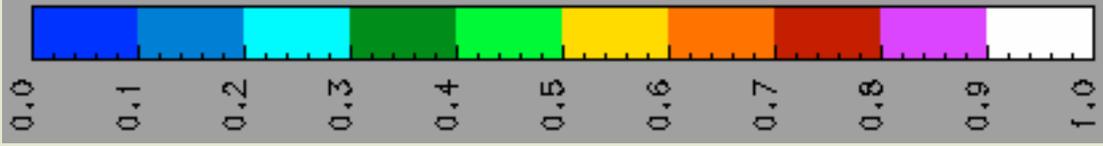
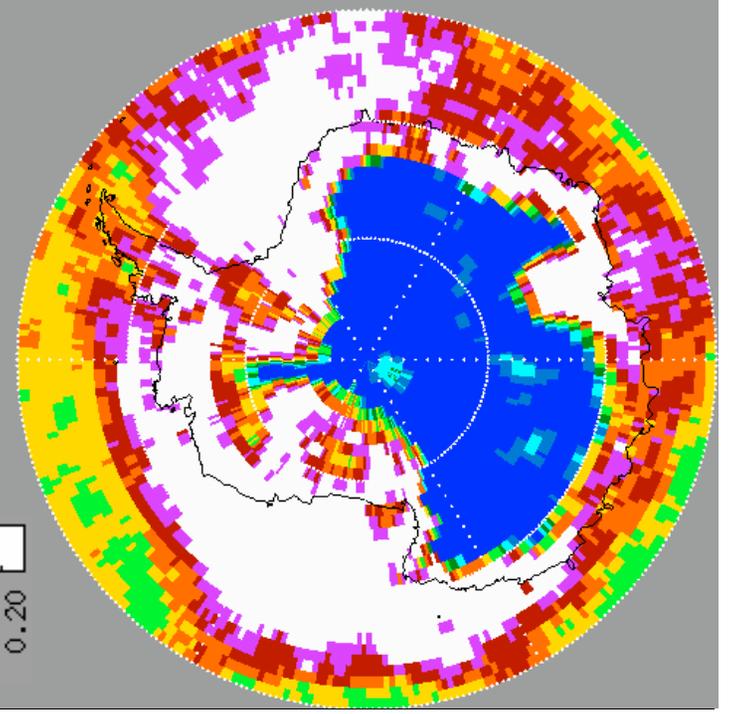


Ed2

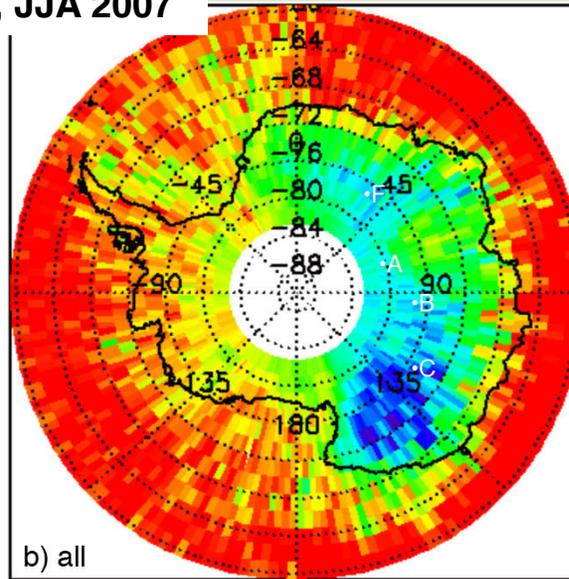
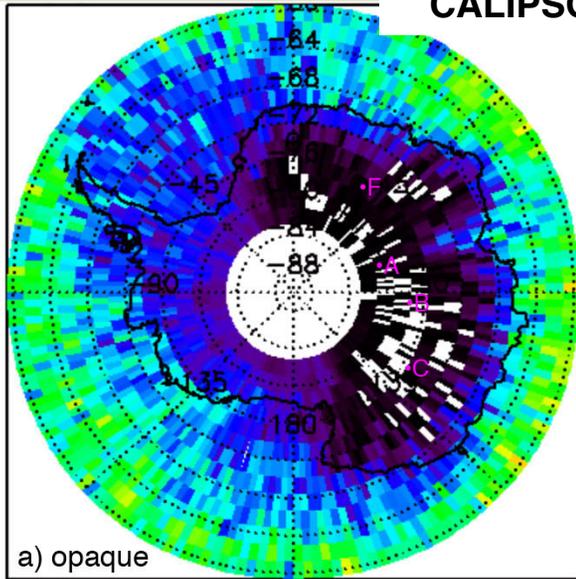


Terra 200708,  
Night Time,  
Cloud Fraction,  
Southern Polar  
Region

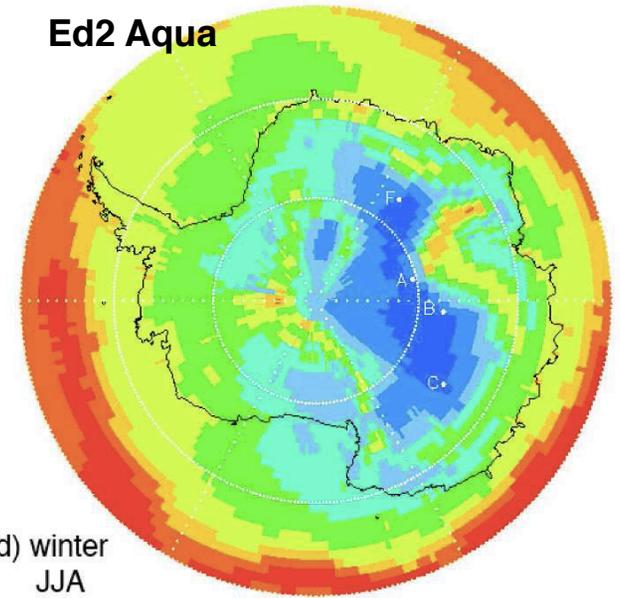
CF Diff (Ed3-Beta2 minus Ed2)



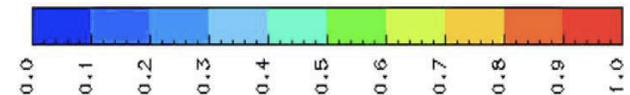
# CALIPSO, JJA 2007



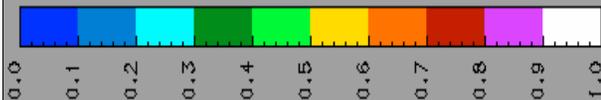
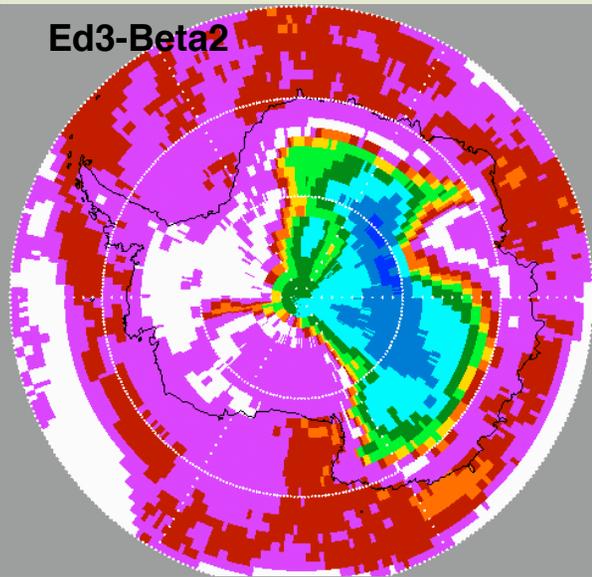
## Ed2 Aqua



d) winter JJA

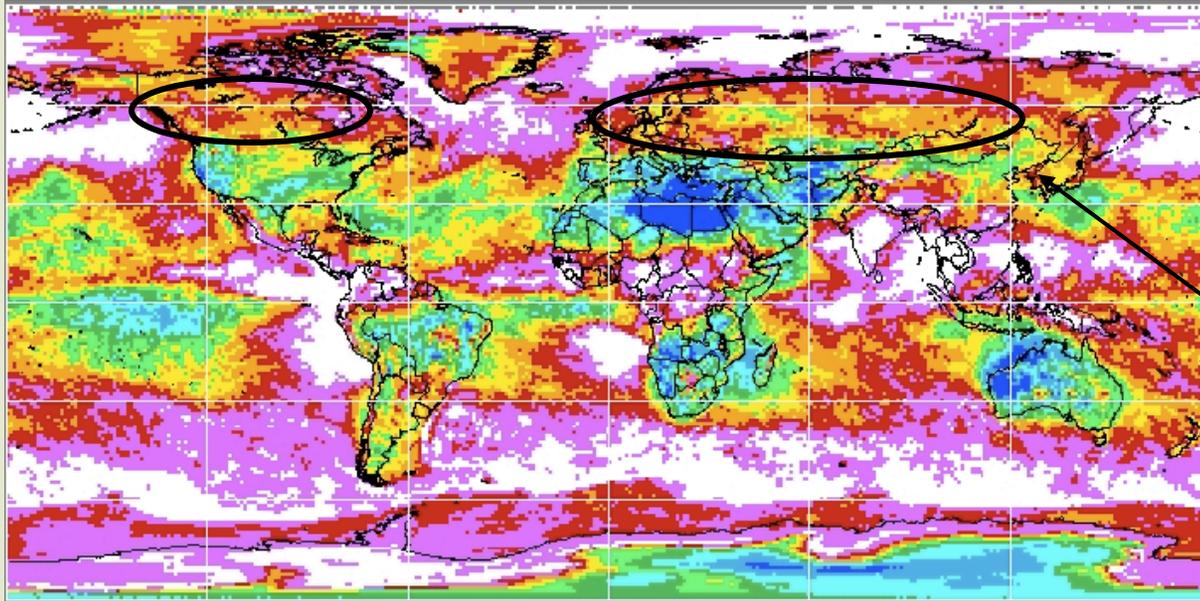


## Ed3-Beta2



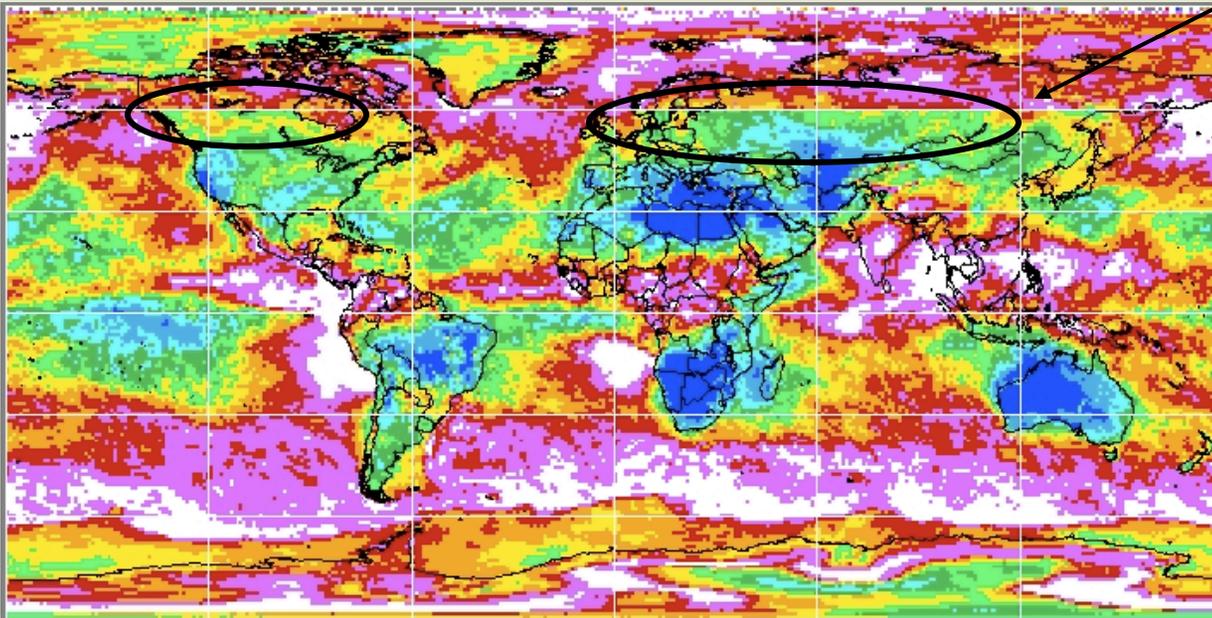
- Ed3-Beta2 possibly too extreme
  - lows too low
  - highs too high
- Ed3-Beta2 comparable to Aqua Ed2 in accuracy

# Ed3-Beta2



Terra 200708,  
**Night Time,**  
Cloud Fraction,

Improved Polar / NonPolar  
Transition



Too much clouds in  
southern hemisphere  
deserts in Ed3-Beta2?

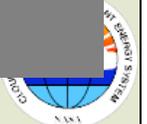
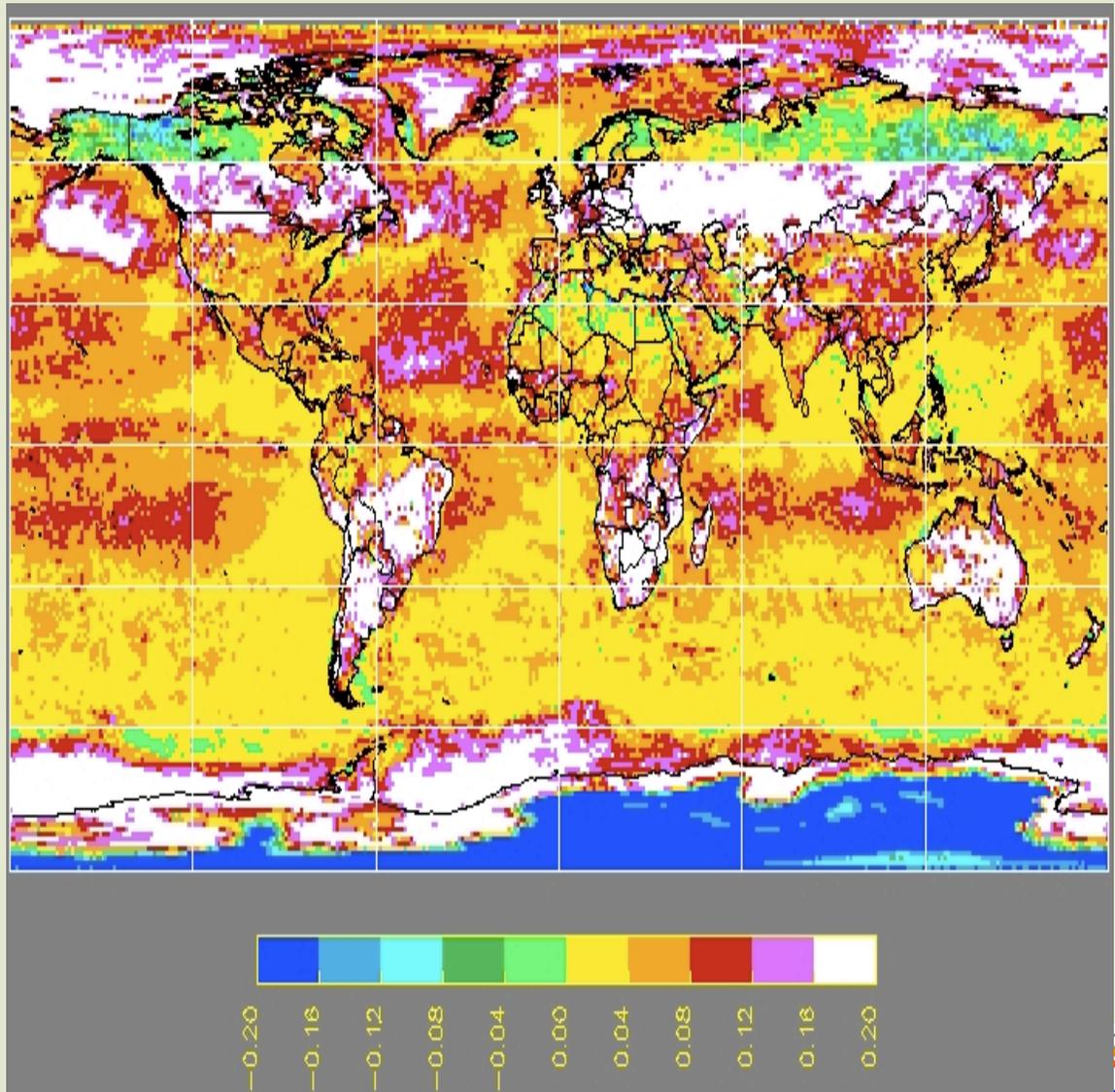
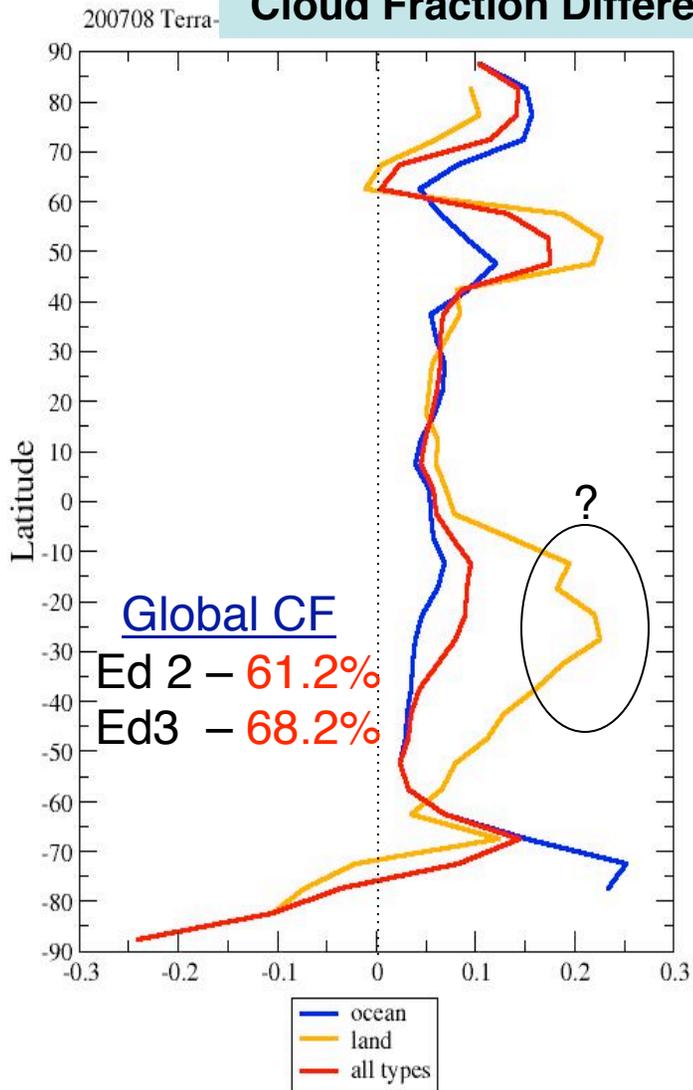


Ed2



# Terra-MODIS 200708 Night Time Cloud Fraction

## Cloud Fraction Difference ( Ed3-Beta2 minus Ed2 )



RGB

CO2 TopHgt

VISST TopHgt

Phase

Mask

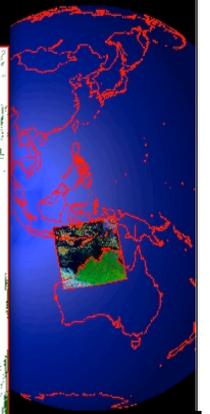
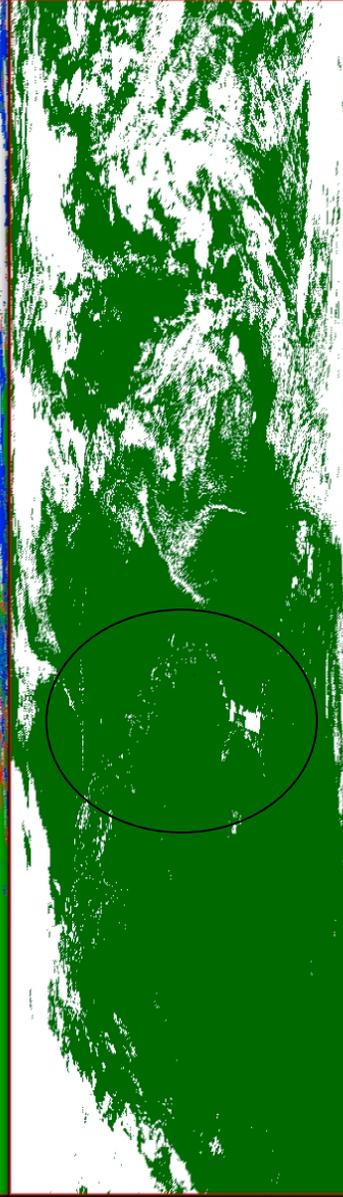
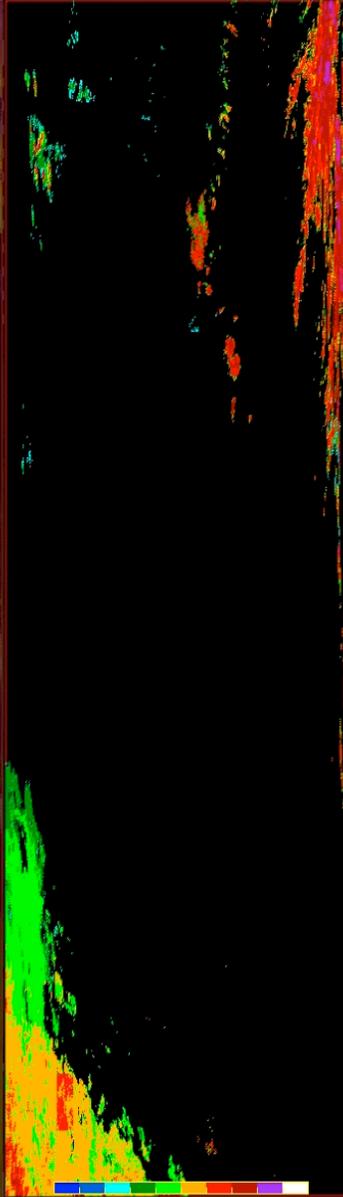
xv 3.10a: 2004071505.03048.Ed3B2D xv 3.10a: 2004071505.03048.Ed3B2D xv 3.10a: 2004071505.03048.Ed3B2D xv 3.10a: 2004071505.03048.Ed3B2D

CEM\_CO2\_Height[km]  
[3.91 13.59] [3.91 13.59]

Top\_Cld\_Height[km]  
[0.10 16.22] [0.20 16.56]

Cloud\_Particle\_Phase  
[9.00 9.00] [1.00 4.00]

CERES\_Cloud\_Mask  
[0.00 65.00] [0.00 3.00]



Aqua  
2004  
0715  
05 H

RGB

CO2 TopHgt

VISST TopHgt

Phase

Mask

xv 3.10a: 2004071501.06096.Ed382D

xv 3.10a: 2004071501.06096.Ed382D

xv 3.10a: 2004071501.06096.Ed382D

xv 3.10a: 2004071501.06096.Ed382D

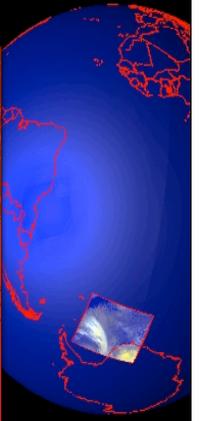
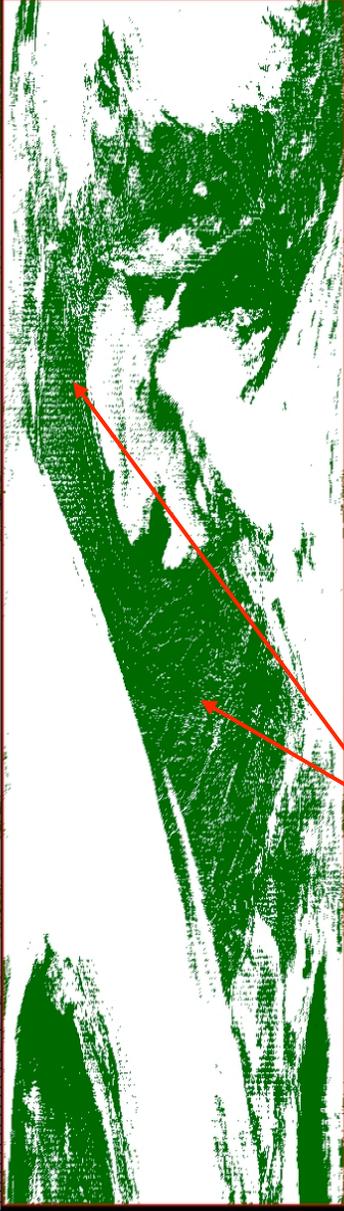
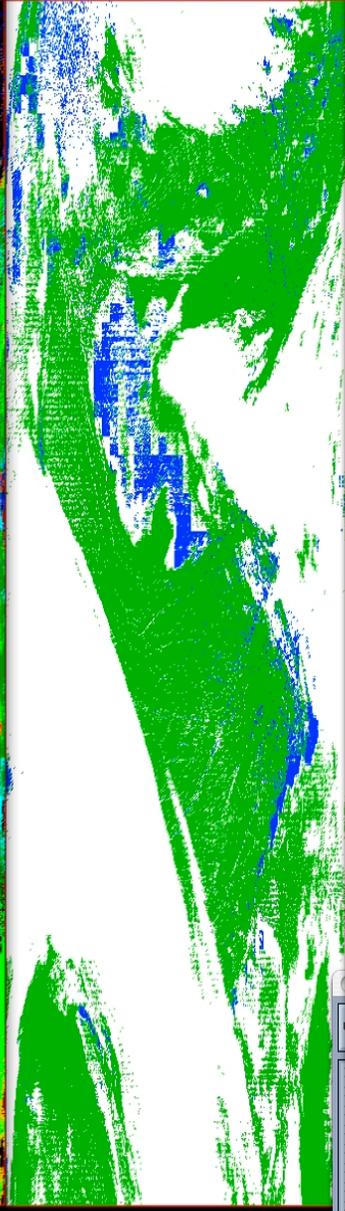
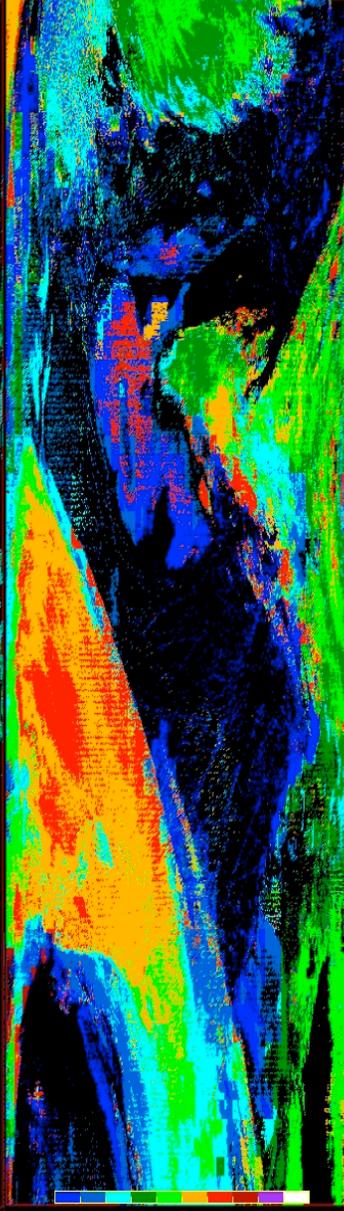
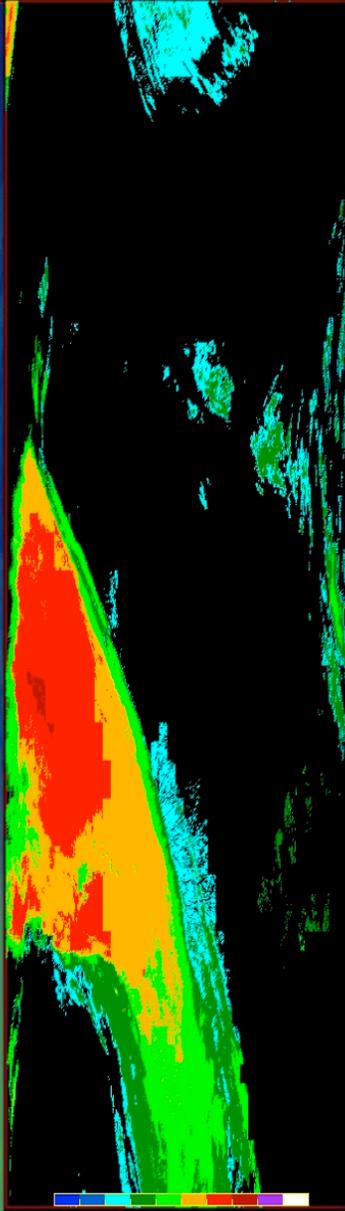
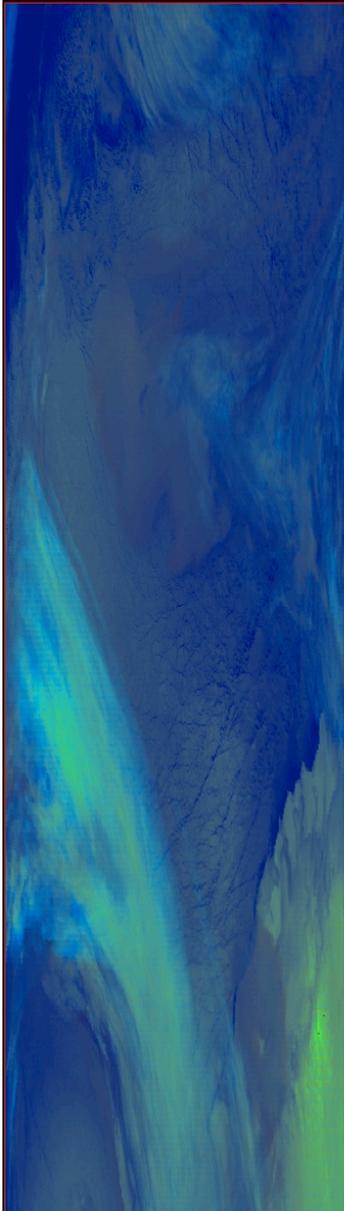
3.10a: 2004071501.06096.E

CEM\_CO2\_Height[km]  
[3.46 11.40] [3.46 11.40]

Top\_Old\_Height[km]  
[0.10 13.99] [0.20 13.99]

Cloud\_Particle\_Phase  
[0.00 9.00] [1.00 4.00]

CERES\_Cloud\_Mask  
[0.00 65.00] [0.00 3.00]



Aqua  
2004  
0715  
01 H

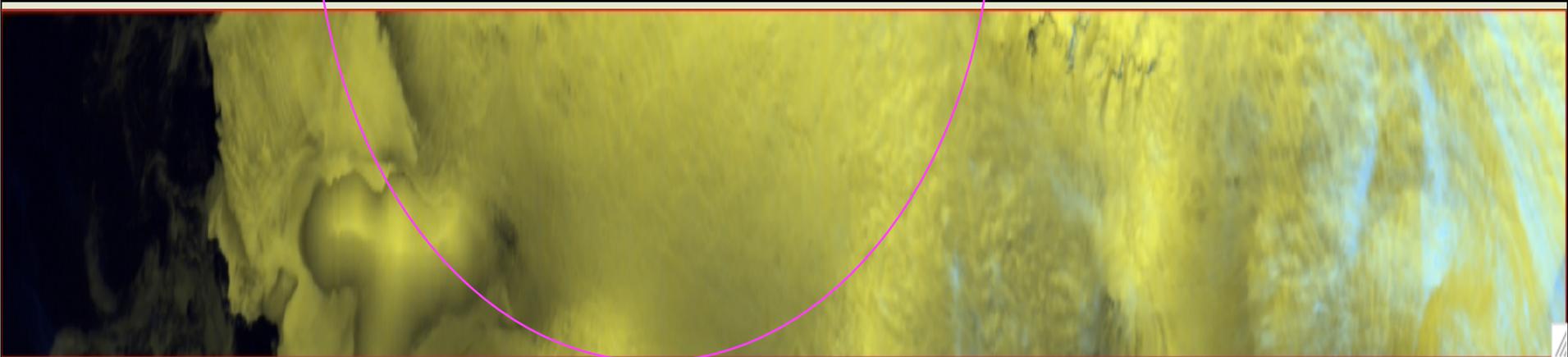
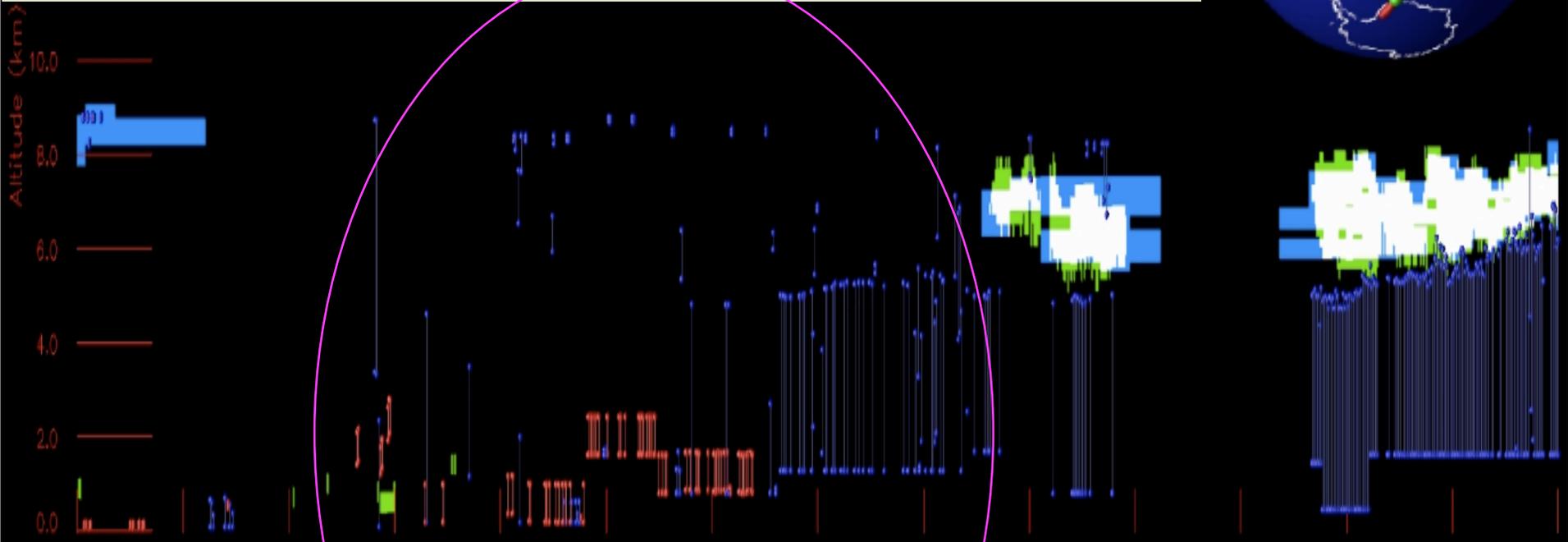
Stripes

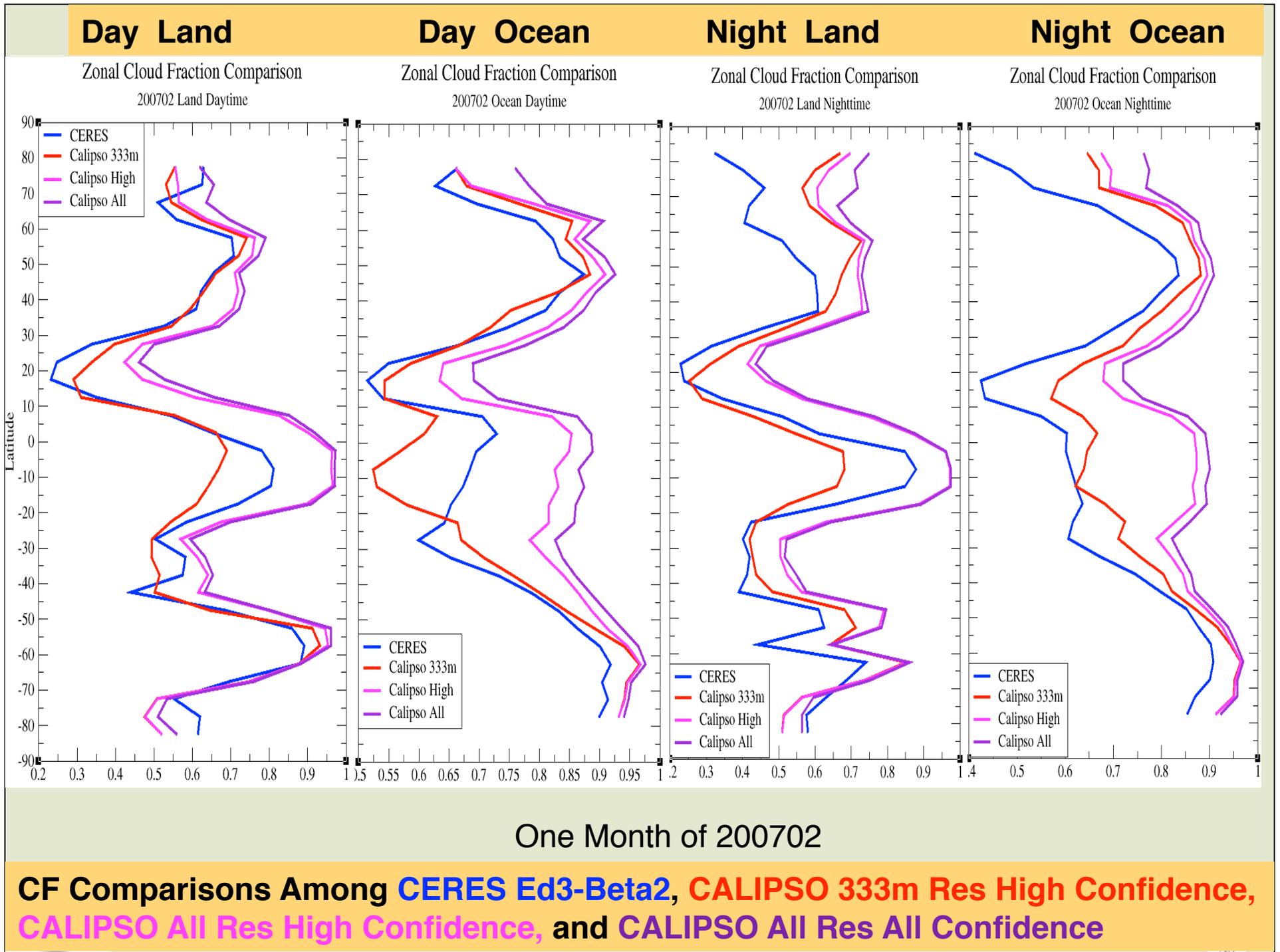


2007 02 01 00H



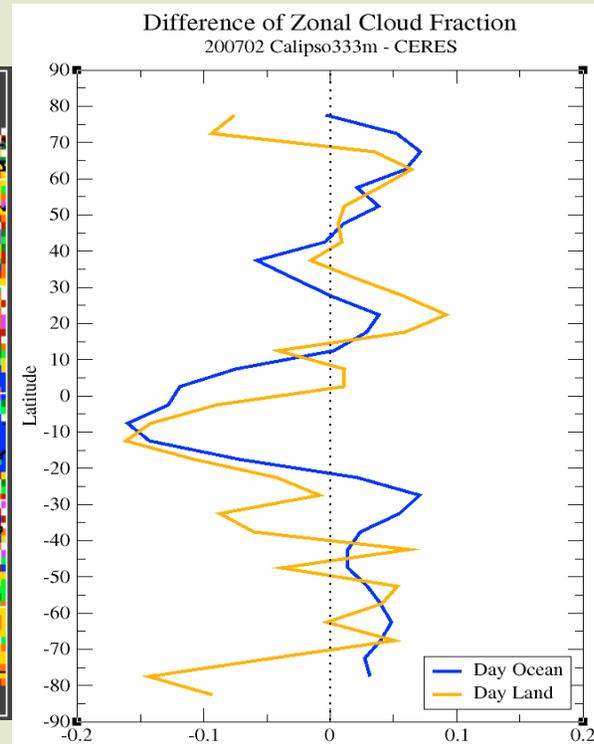
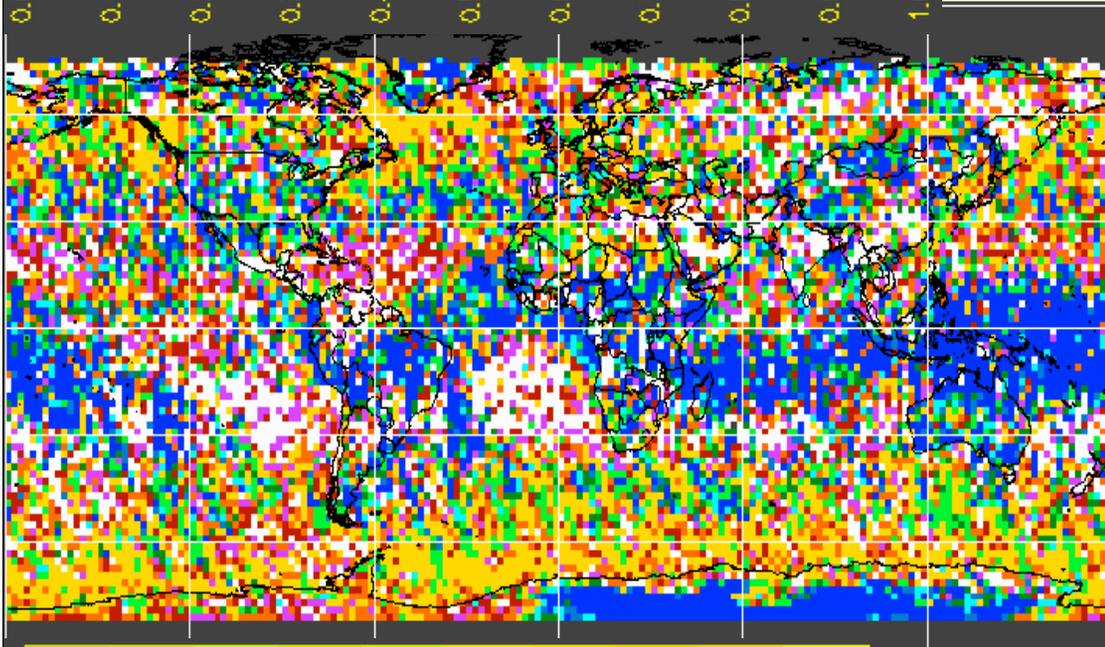
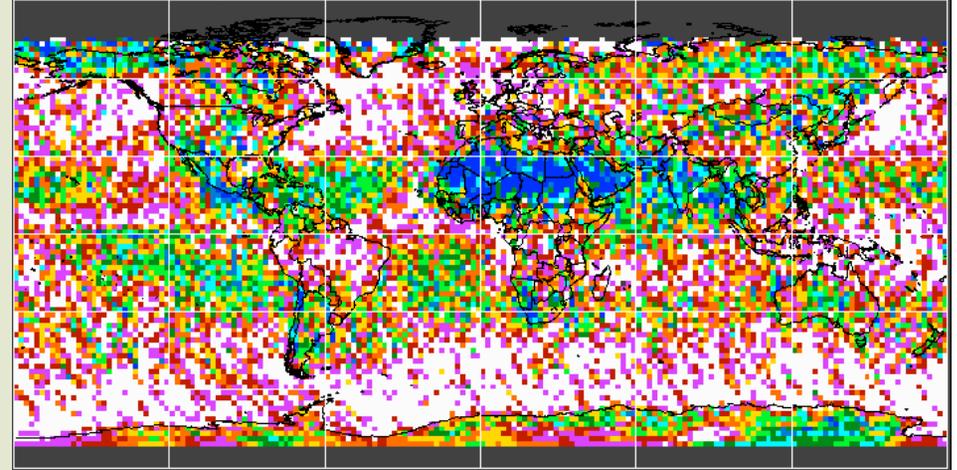
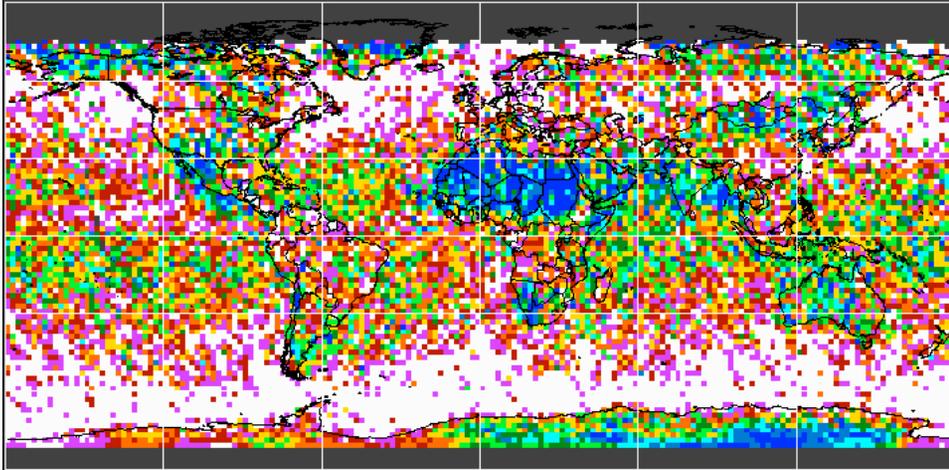
False Clouds





CALIPSO CF (333m below 8.2km, all res above 8.2km)

CERES CF



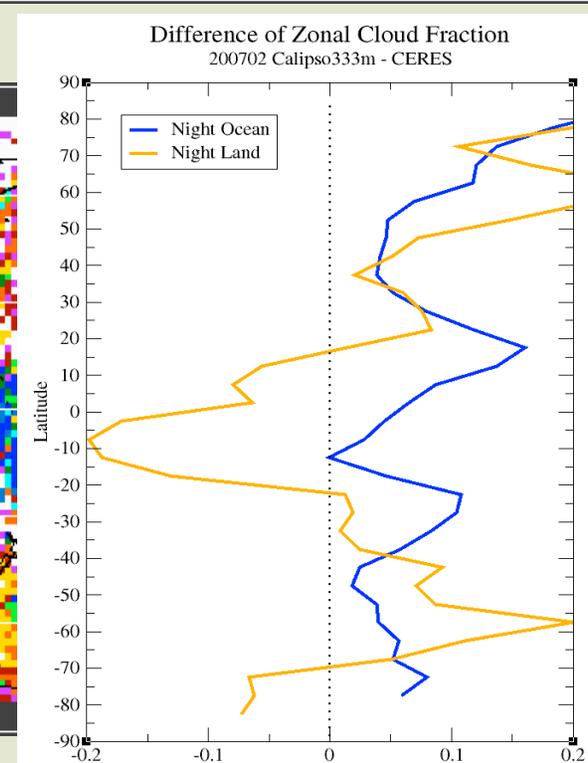
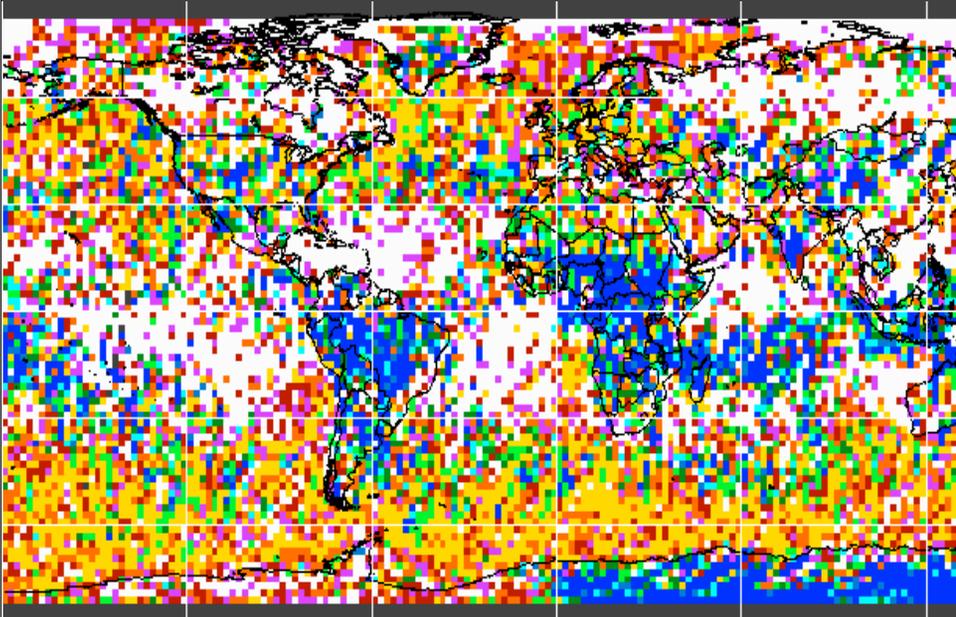
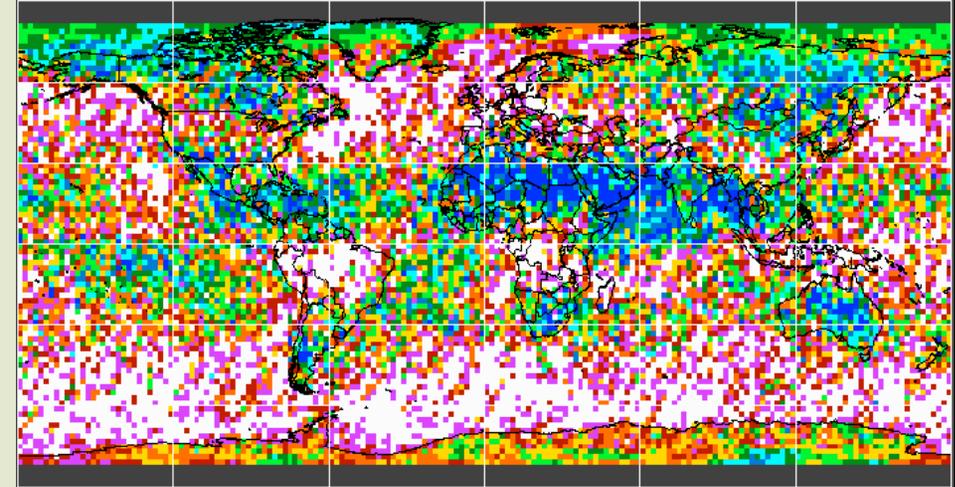
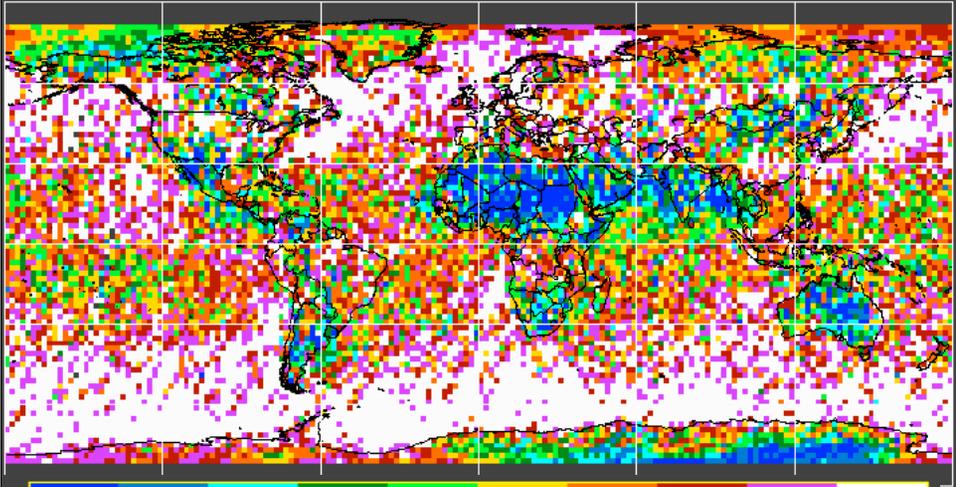
200702  
Day  
Time

Diff CF (CALIPSO 330m - CERES)



CALIPSO CF (333m below 8.2km, all res above 8.2)

CERES CF



200702  
Night  
Time

Diff CF (CALIPSO 330m - CERES)



# Day Land

# Day Ocean

# Night Land

# Night Ocean

Zonal Cloud Fraction Comparison

Zonal Cloud Fraction Comparison

Zonal Cloud Fraction Comparison

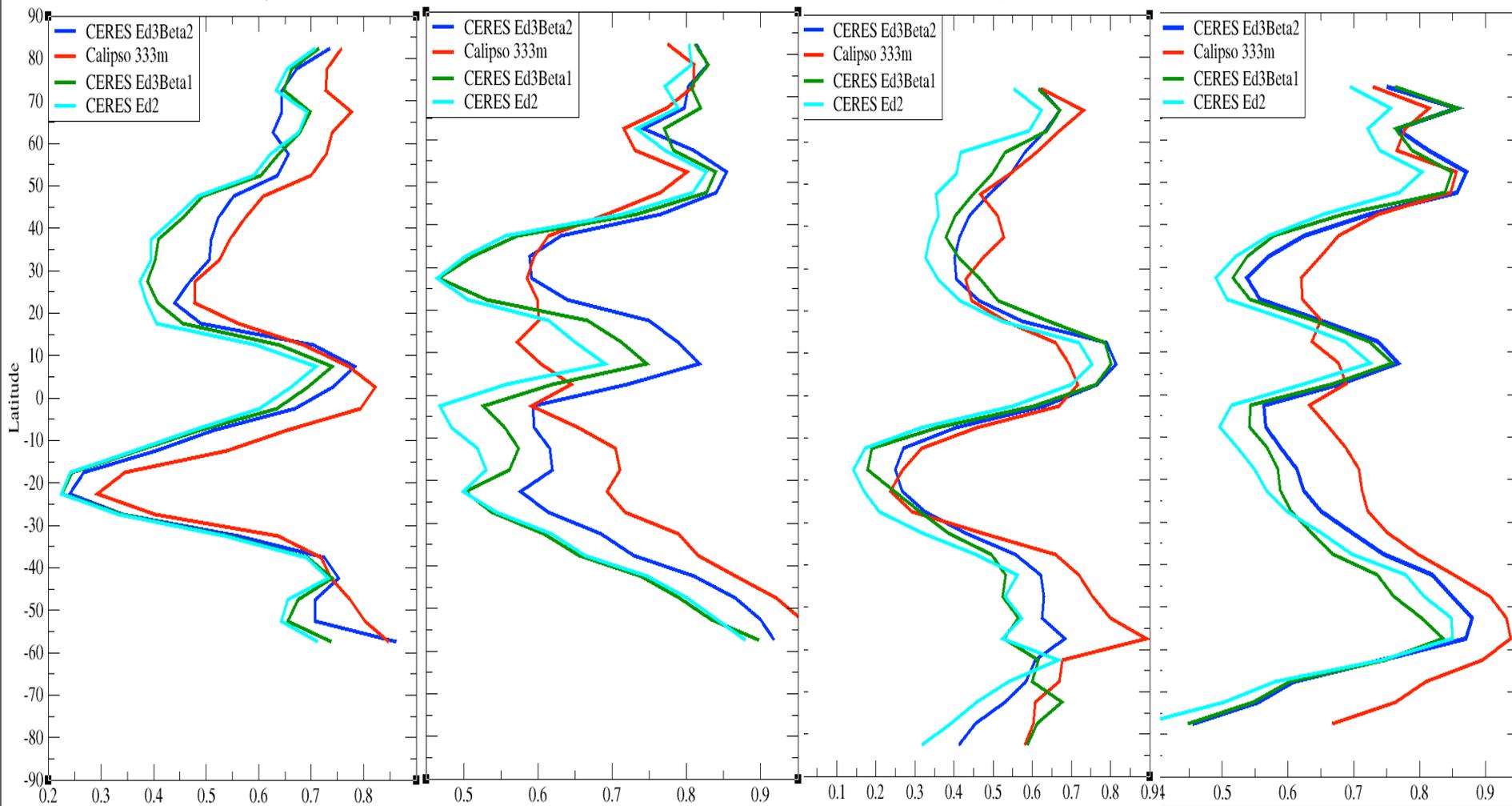
Zonal Cloud Fraction Comparison

200607 Land Daytime

200607 Ocean Daytime

200607 Land Nighttime

200607 Ocean Nighttime



One Month of 200607

CF Comparisons Among CERES Ed3-Beta2, Ed3-Beta1, Ed2 and CALIPSO 333m



# Phase

## Water clouds

	Ed2	Ed3-2
polar	0.379	0.443
Npolar	0.348	0.383
Global	0.352	0.390

## Ice Clouds

	Ed2	Ed3-2
polar	0.327	0.313
Npolar	0.215	0.247
Global	0.228	0.255



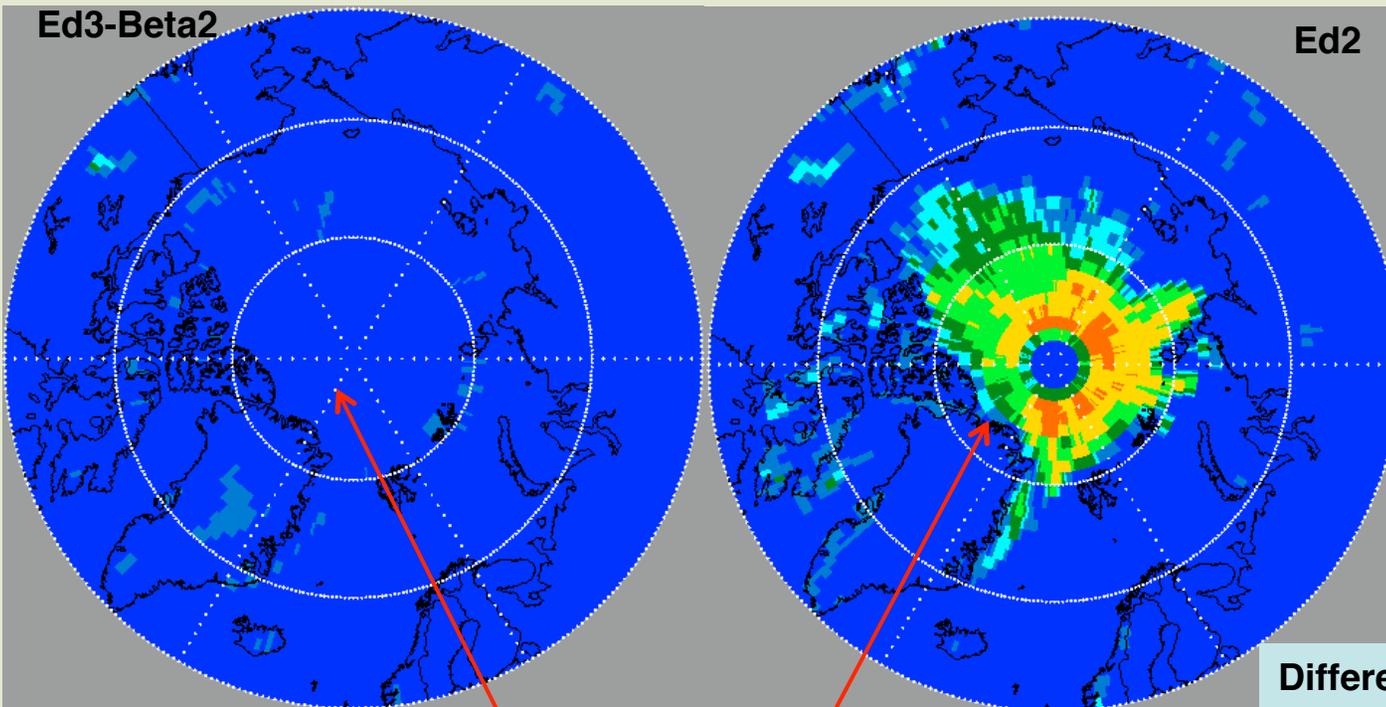
# No Retrieval Cloud Fraction



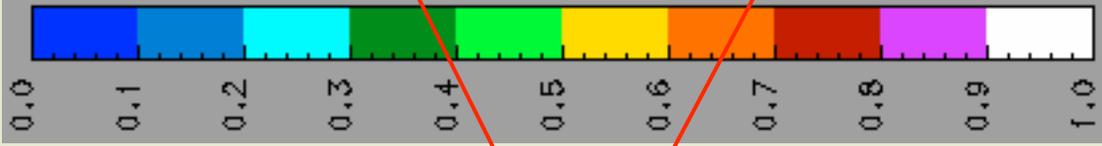
Ed3-Beta2

Ed2

Terra 200708,  
Day Time,  
No-Retrieval-Cloud  
Fraction



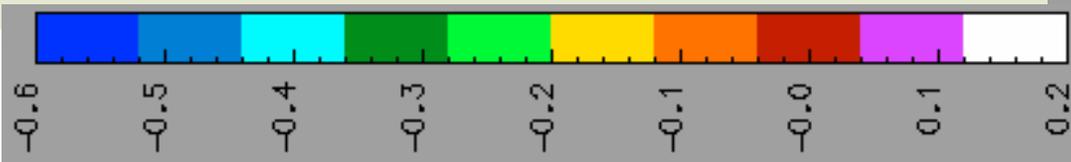
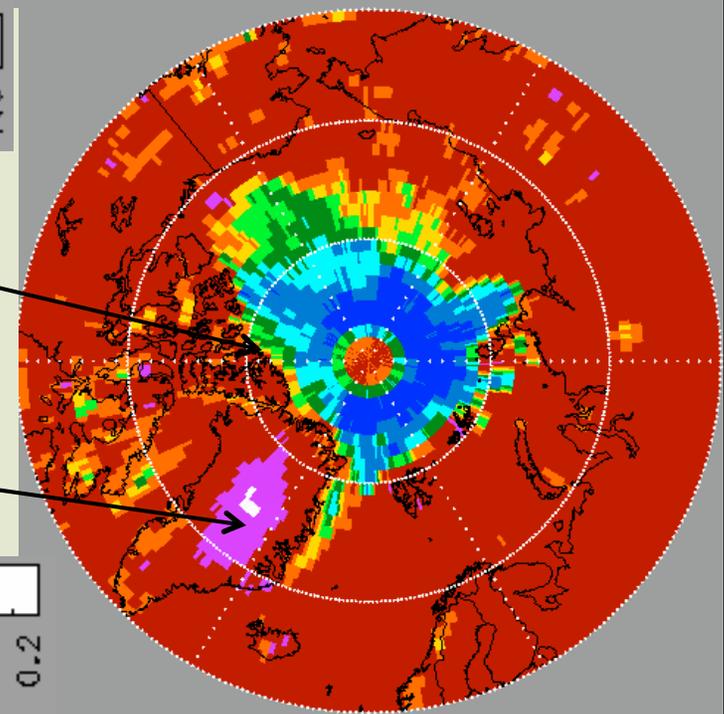
Difference (Ed3-Beta2 minus Ed2)



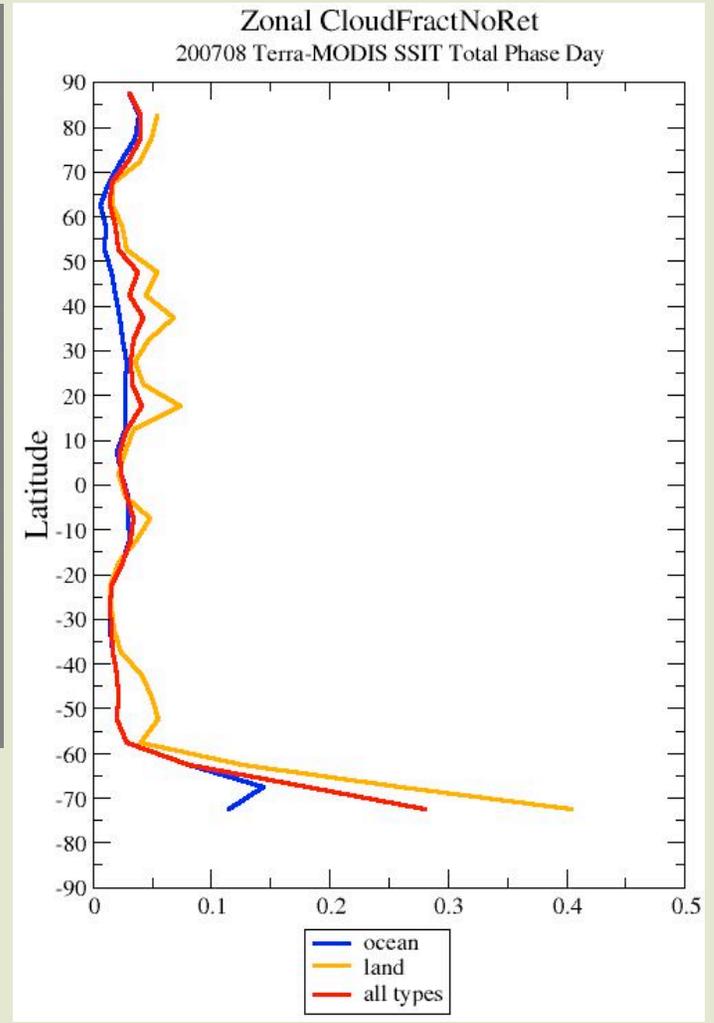
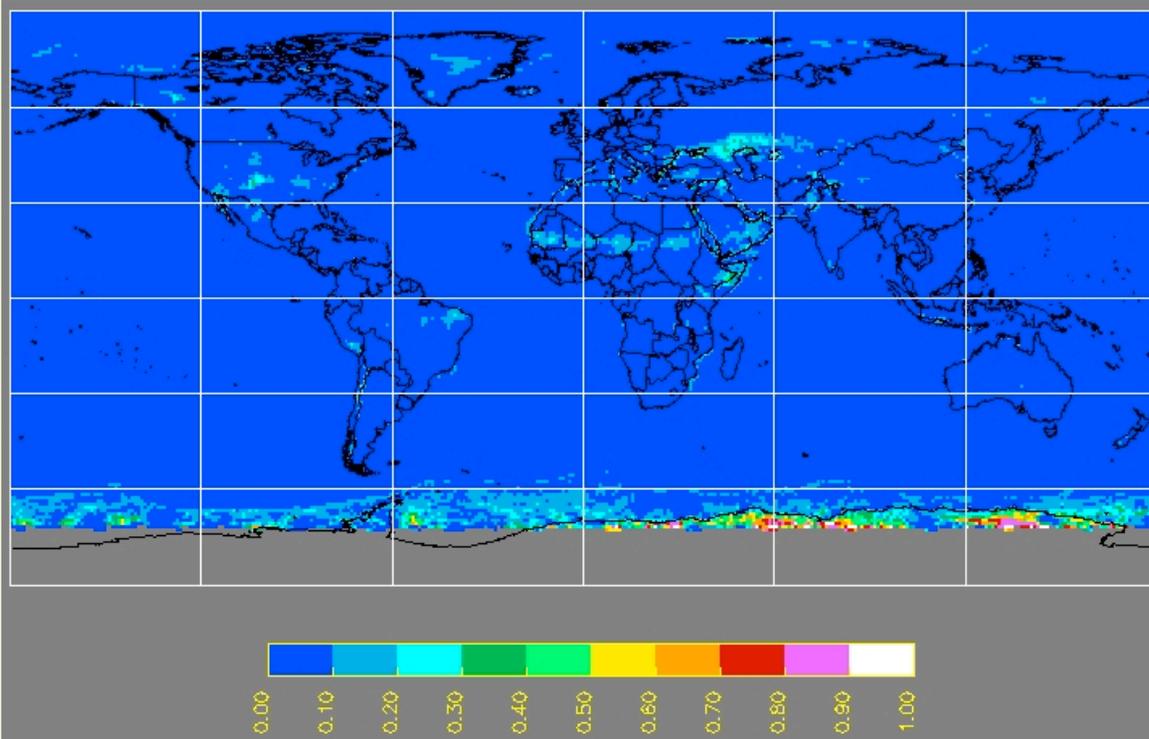
Improved by ~ 50%



False cloud detection ??



# Daytime No-Retrieval Summary, Terra, Ed3-β2, July 2007



- Deserts and perm snow have most no-retrievals
- Most new clouds retrieved

## No-Ret Frac   Ret Frac

Global:	0.032	0.640*
Polar:	0.076	0.753
NonPolar:	0.027	0.630



\* MOD06 Collection-5 Ret Frac ~ 0.54



## RETRIEVALS

- Develop alternate method for thin cirrus no-retrievals,
- Blend lapse rates at coast
- Forcing VISST tau to CO2 value: use looser threshold (100, 150 mb)?
- Put in and verify 2.13- $\mu\text{m}$  corr-k code: limitations on 2.13  $\mu\text{m}$
- No longer running old 4-chan CO2
- Insert new thickness parameterizations; polar parameterizations?
- Put in water cloud top height adjustments?  $\sim 100$  m
- Correct lapse rates; test Zuidema method
- Normalize Aqua and Terra VIS channel calibrations?; which is best?
- $\tau$  limit: 150
- no 250-m data, no partial cloud retrievals for Ed3
- test night retrievals: can we loosen the constraints?
- Complete height & ML testing using CALIPSO-Cloudsat data



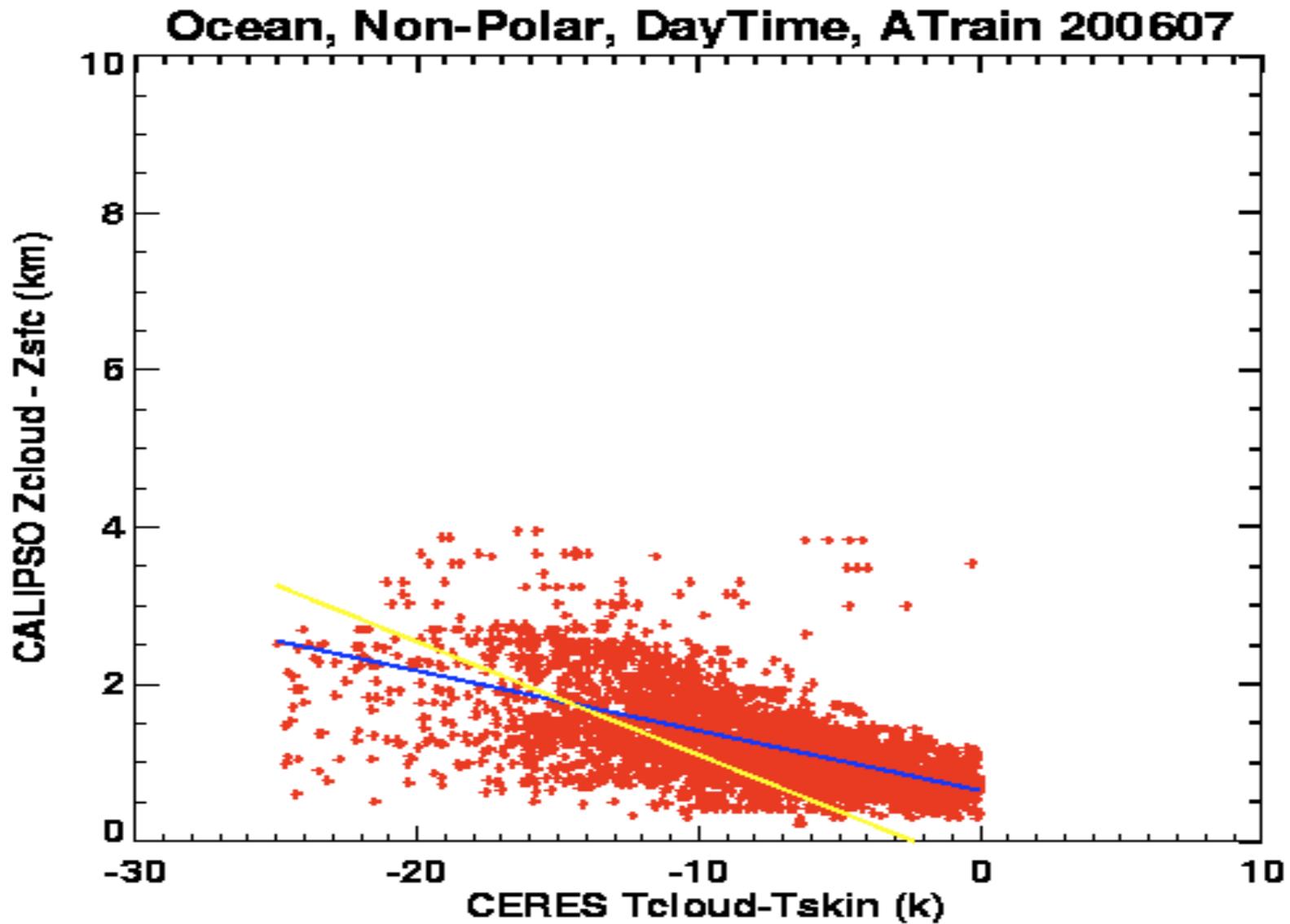
# Cloud Height

- more cumulus clouds & thin cirrus detected
  - warmer cumulus, lower clouds
- ozone optical depth was overestimated by 13.3% in Ed2
  - tau decreases, ice cloud heights increase
- CO2 heights used to adjust thin cirrus when needed
  - thin ice cloud heights increase
- new surface & lat-dependent lapse rate introduced
  - ocean: water heights rise by 0.22 km
  - land: water heights drop by 0.17 km



Blue:  $Z_{cloud} - Z_{scf} = 0.65 - 0.076 (T_{cloud} - T_{skin})$

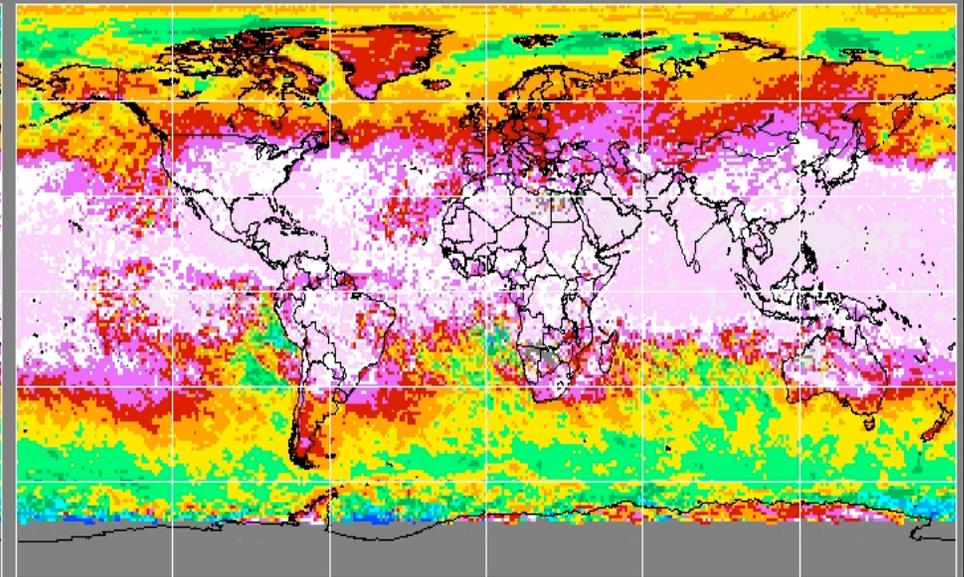
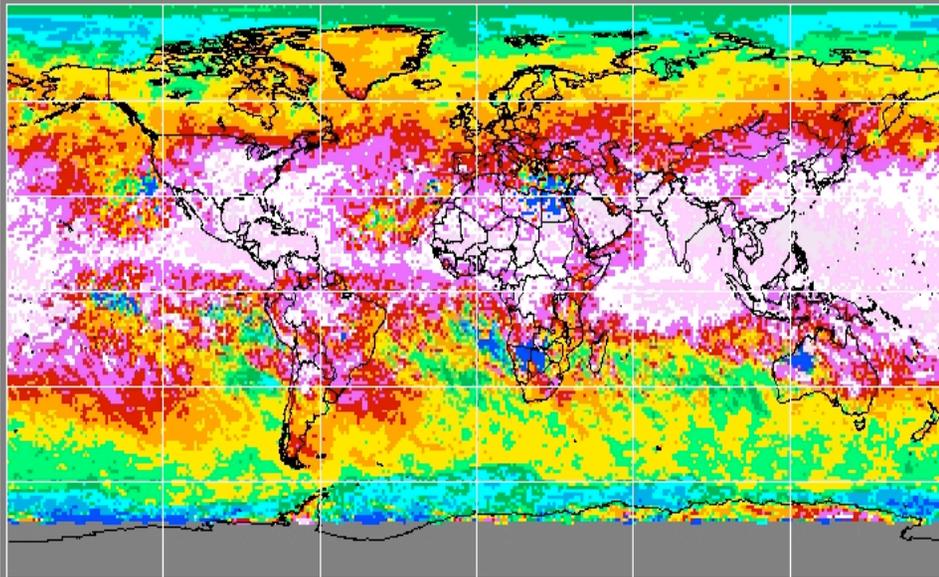
Yellow: Zuidema:  $Z_{cloud} - Z_{scf} = -0.34 - 0.144 (T_{cloud} - T_{skin})$



# Daytime Ice Cloud Eff Height, Terra, July 2008

Ed2

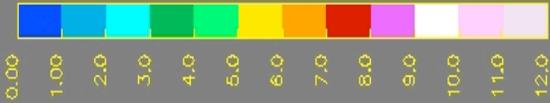
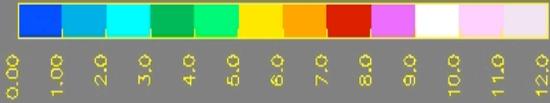
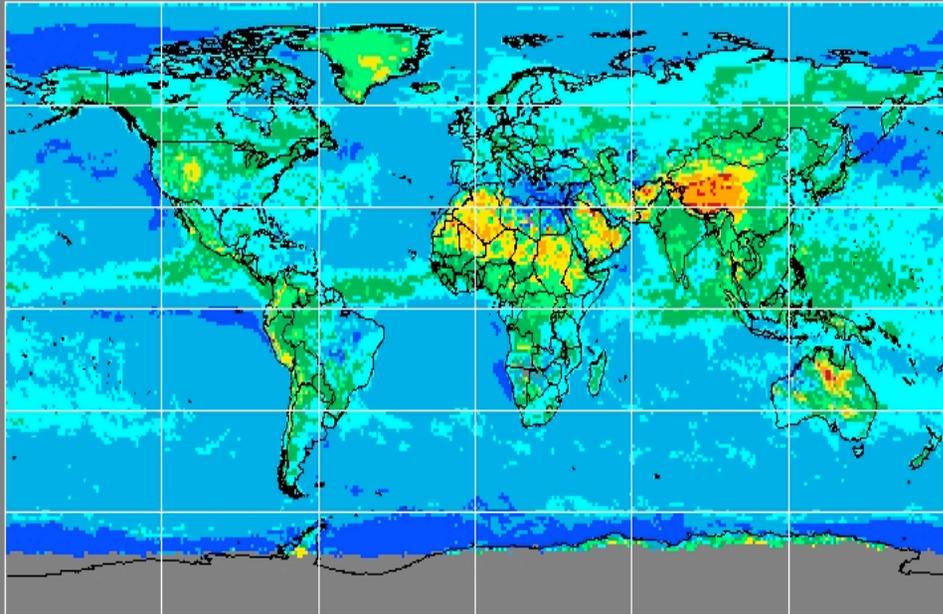
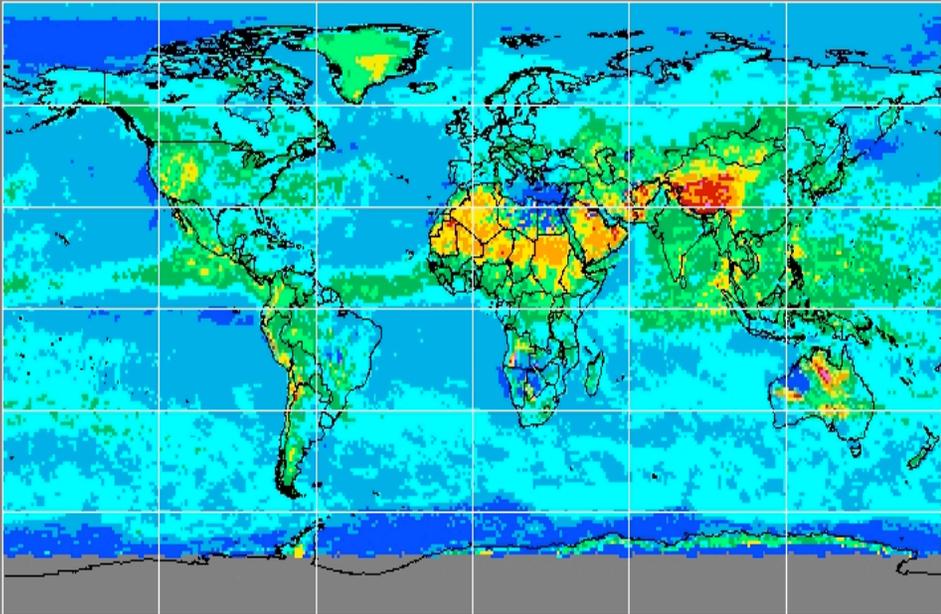
Ed3-beta2



# Daytime Water Cloud Eff Height, Terra, July 2008

Ed2

Ed3-beta2



Water Phase	Ed3Beta2		Ed2		Ed3Beta2 – Ed2	
	Ocean	Land	Ocean	Land	Ocean	Land
Eff Cld Temp (K)						
Global	278.1	274.8	277.1	272.5	0.9	2.2
Polar	261.5	259.5	261.2	259.4	0.3	-0.2
NonPolar	280.2	276.5	279.2	274.0	1.0	2.5

Warmer Clouds (Ed3-Beta2, except Polar) + CALIPSO-Derived Lapse Rate

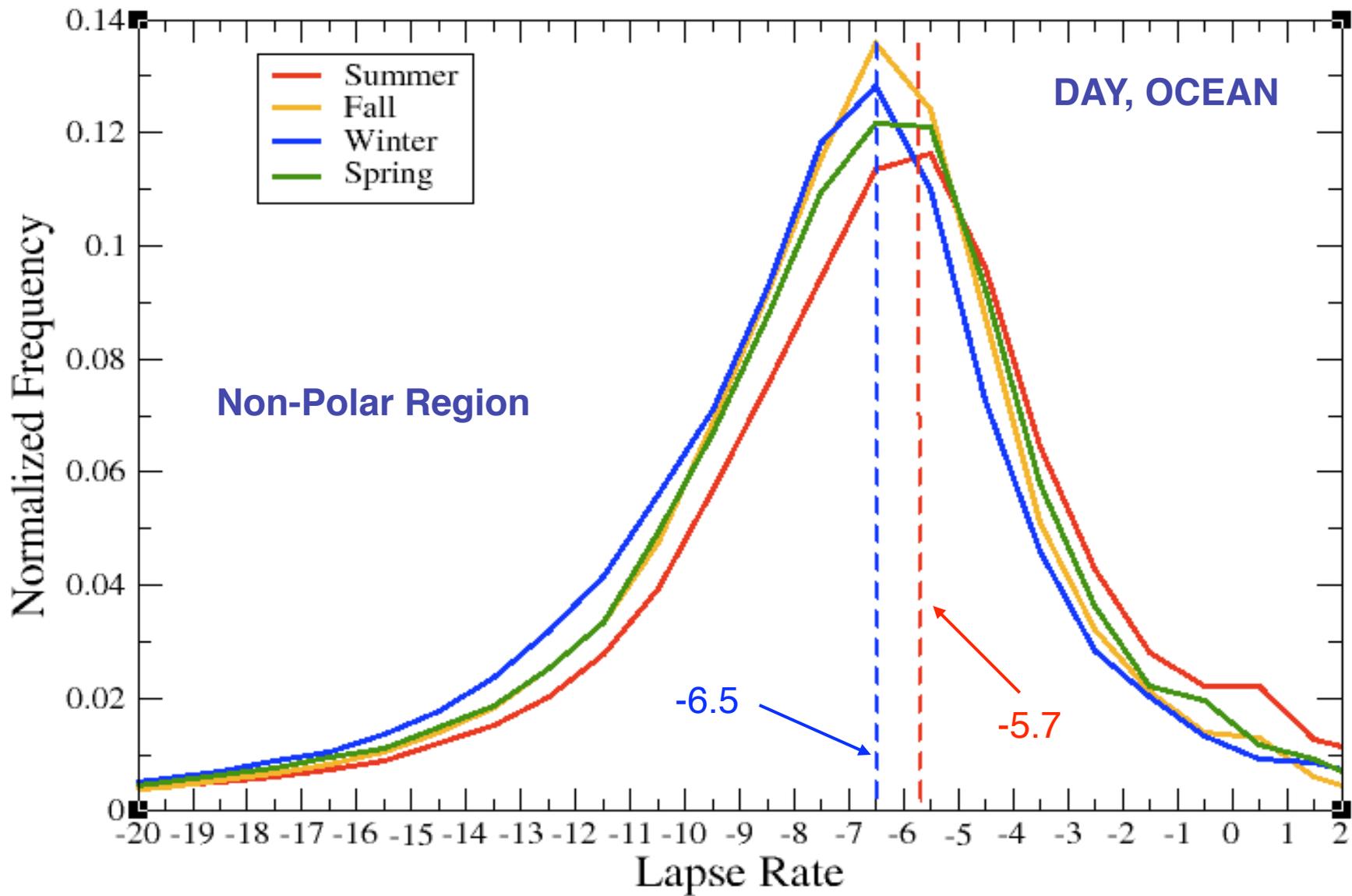
Water Phase	Ed3Beta2		Ed2		Ed3Beta2 – Ed2	
	Ocean	Land	Ocean	Land	Ocean	Land
Eff Cld Hgt (km)						
Global	1.9	3.3	2.1	3.5	-0.25	-0.18
Polar	1.4	2.7	1.5	2.6	-0.12	0.14
NonPolar	2.0	3.4	2.2	3.6	-0.27	-0.21

CO2 Heights & decreased tau Result

Ice Phase	Ed3Beta2		Ed2		Ed3Beta2 – Ed2	
	Ocean	Land	Ocean	Land	Ocean	Land
Eff Cld Hgt (km)						
Global	7.9	8.8	7.2	7.8	0.64	0.91
Polar	5.1	6.8	4.3	5.6	0.84	1.12
NonPolar	8.2	9.0	7.6	8.1	0.61	0.89



# Seasonal Lapse Rate Histogram, ATrain Aqua-MODIS Day, Ocean (200607, 200610, 200701, 200704)



## New Height Products

- Cloud-top height, temperature
  - height used to report cloud-top pressure in Ed2, but not recorded
  - optically thick ice clouds now have top height different from effective height

if ice phase, and  $\tau > 7.99$  and  $\text{EffHgt} > 4.2$

$$\text{TopHgt} = 1.79 + 1.014 * \text{effHgt}$$

$$\text{delz} = (\text{TopHgt} - \text{effHgt}) * \cos(\text{vza})$$

$$\text{finalTopHeight} = \text{effHgt} + \text{delz}$$

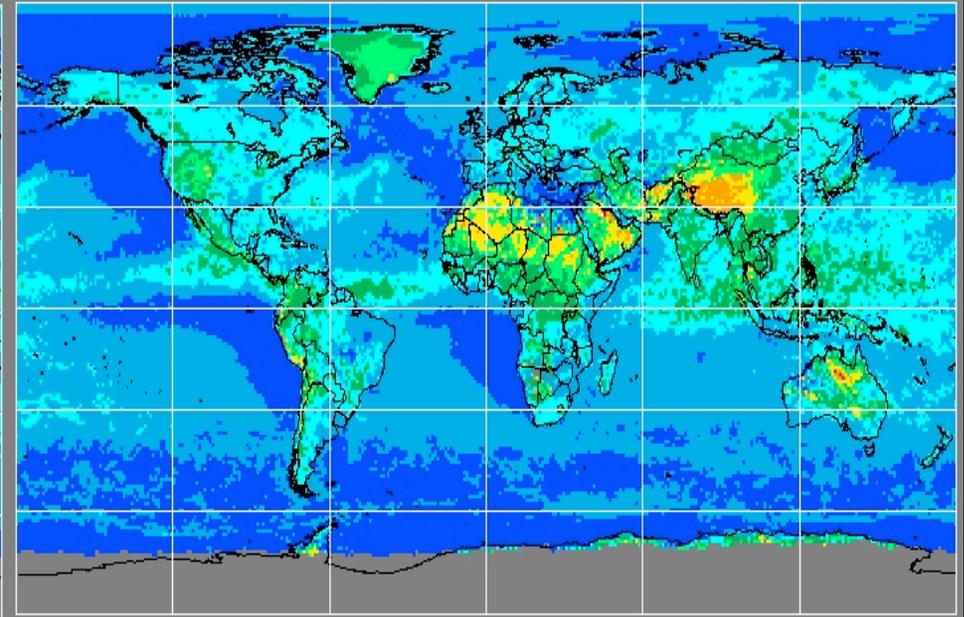
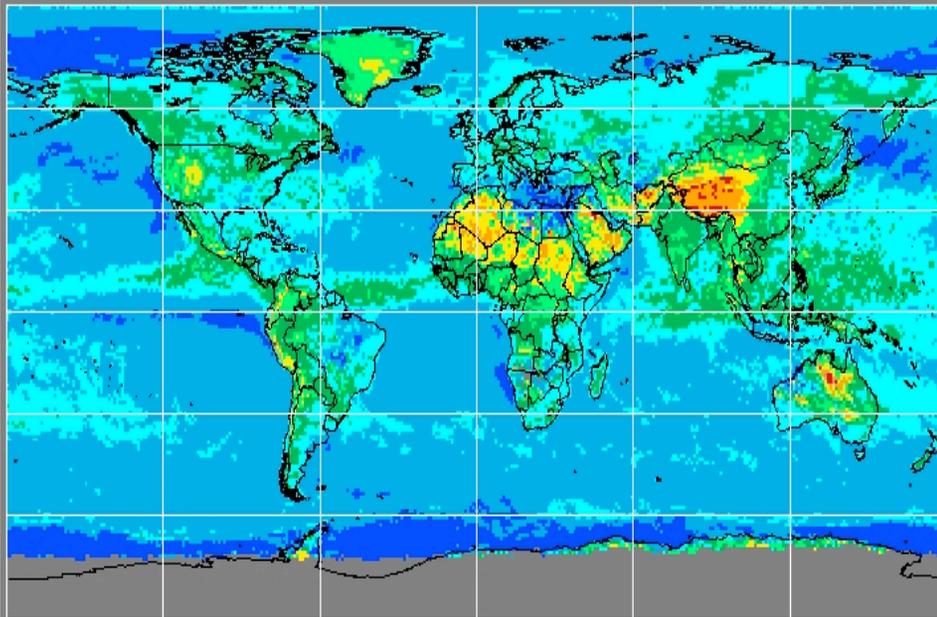
- Cloud-base height, temperature
  - height used to report cloud-base pressure in Ed2, not recorded
  - Ed3 computed based on new thickness parameterizations



# Ed3 Daytime Water Cloud Heights, Terra, July 2008

Top

bottom



RGB

CO2 TopHgt

VISST TopHgt

Phase

Tau

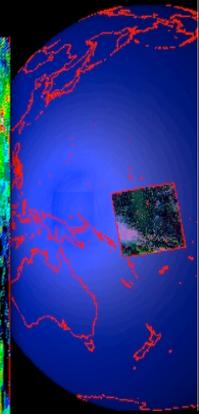
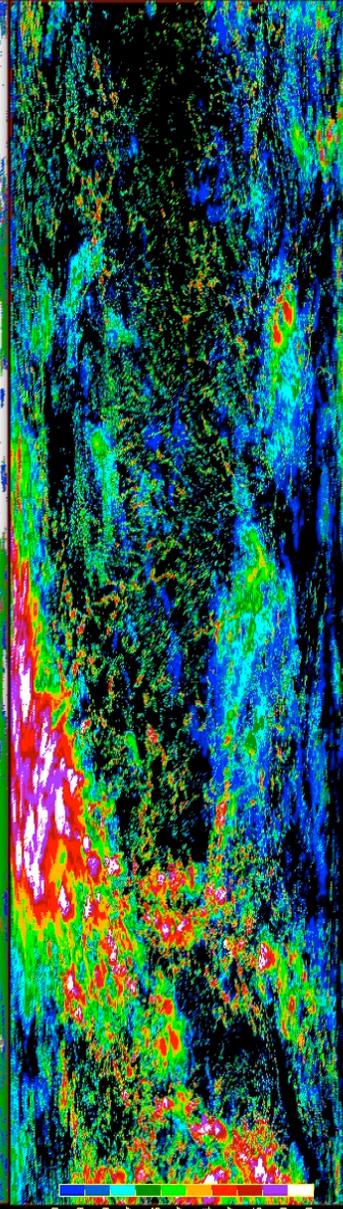
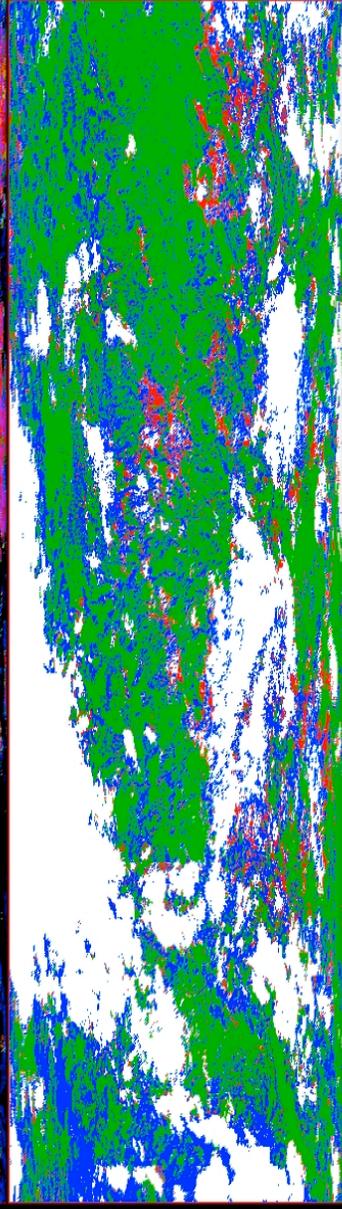
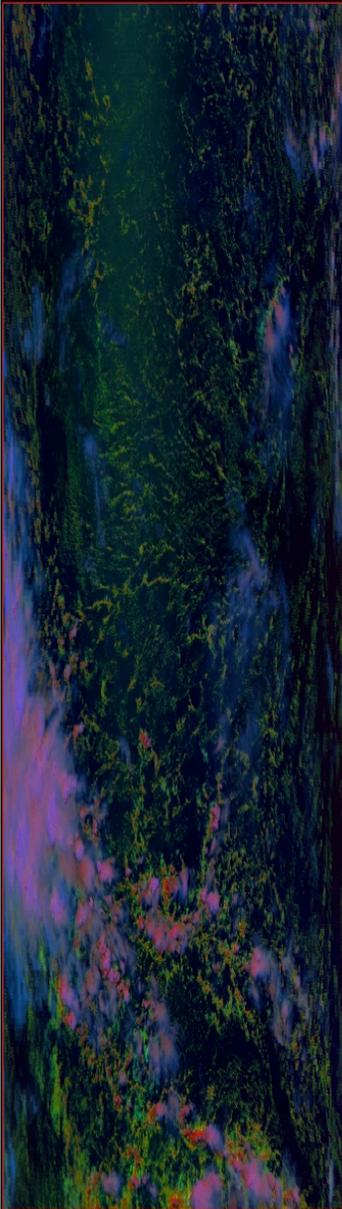
xv 3.10a: 2004071502.00000.Ed3B2D xv 3.10a: 2004071502.00000.Ed3B2D xv 3.10a: 2004071502.00000.Ed3B2D xv 3.10a: 2004071502.00000.Ed3B2D xv 3.10a: 2004071502.00000.Ed3B2D

CEM\_CO2\_Height[km]  
[3.92 16.53] [3.92 16.53]

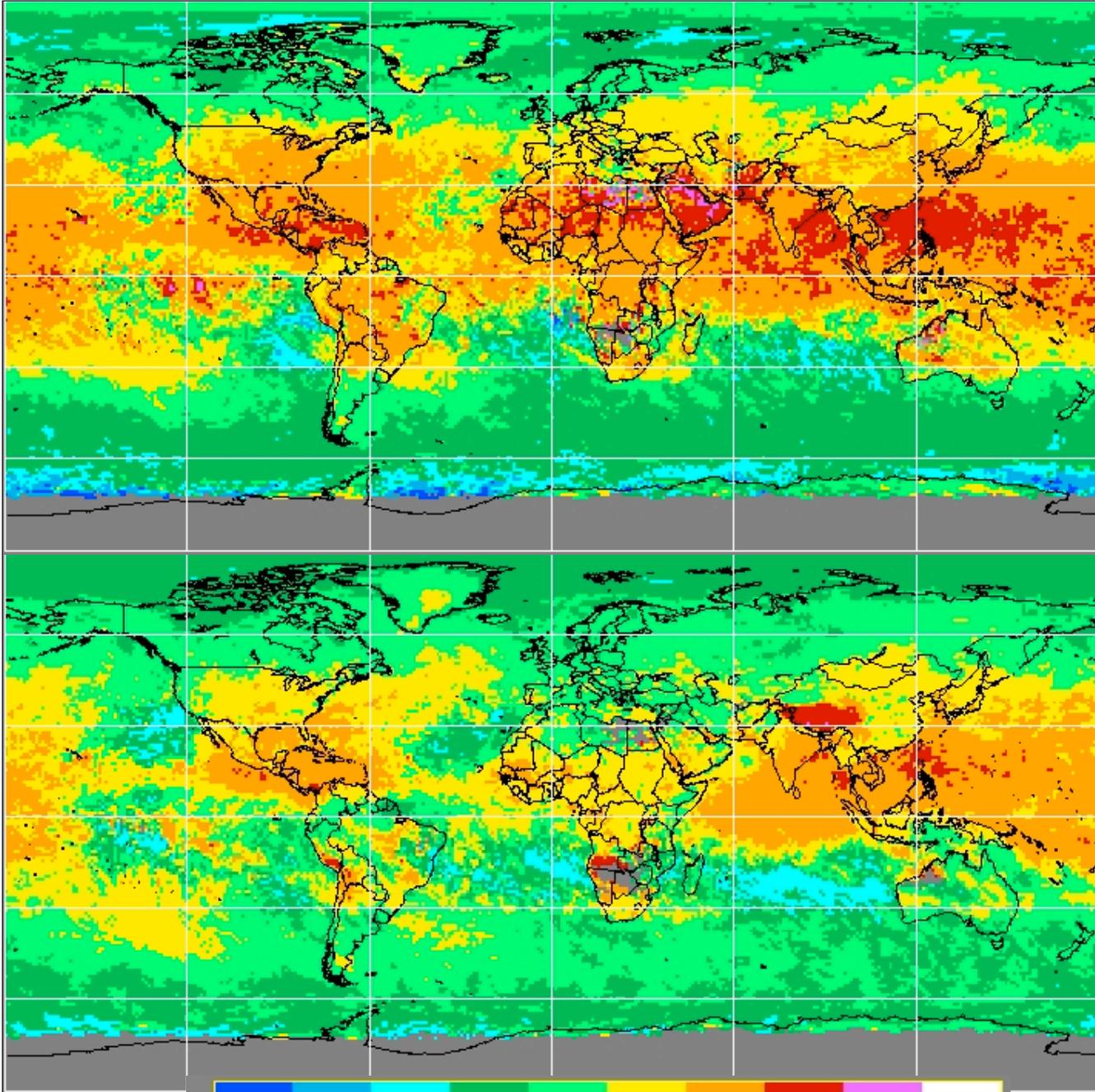
Top\_Cld\_Height[km]  
[0.10 15.64] [0.20 15.75]

Cloud\_Particle\_Phase  
[9.00 9.00] [1.00 4.00]

Eff\_Cld\_Optical\_Depth  
[4.01 32.00] [0.05 152.39]



Aqua  
2004  
0715  
02 H



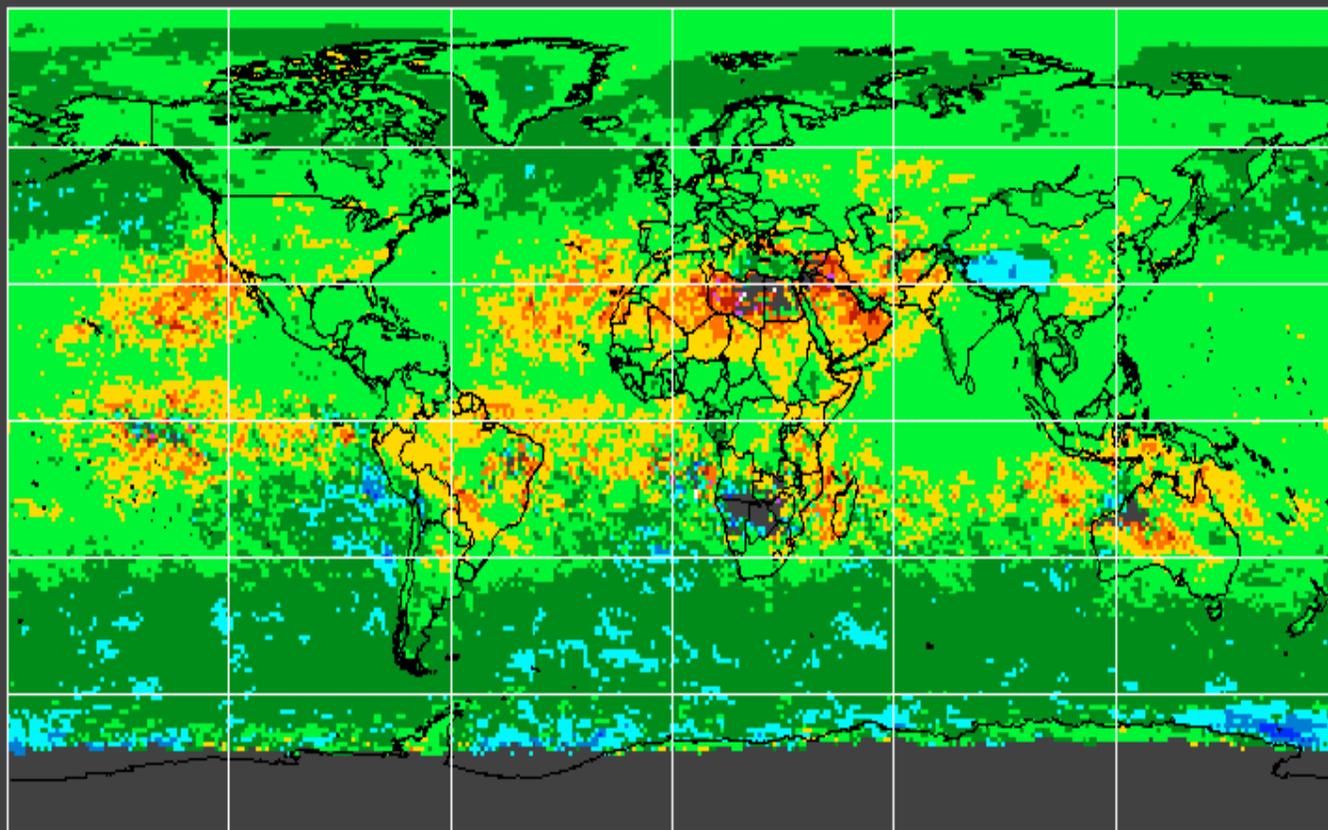
Terra 200708,  
Day Time,  
Cloud Top Height

VISST, Ice,  
Cloud Top  
Height (km)

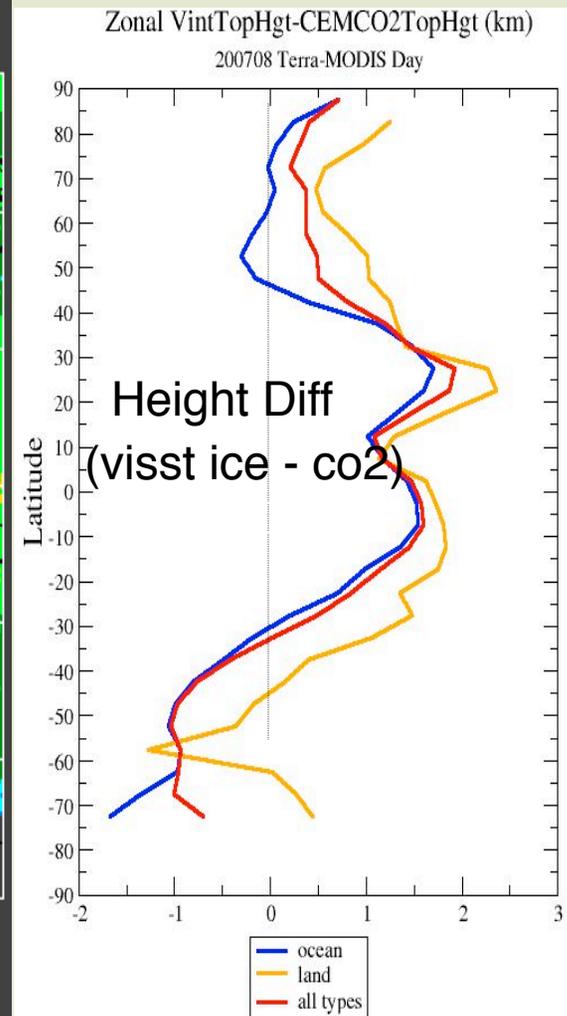
CO2 Cloud Top  
Height (km)



# VISST Ice Cloud Top Height - CO2 Cloud Top Height



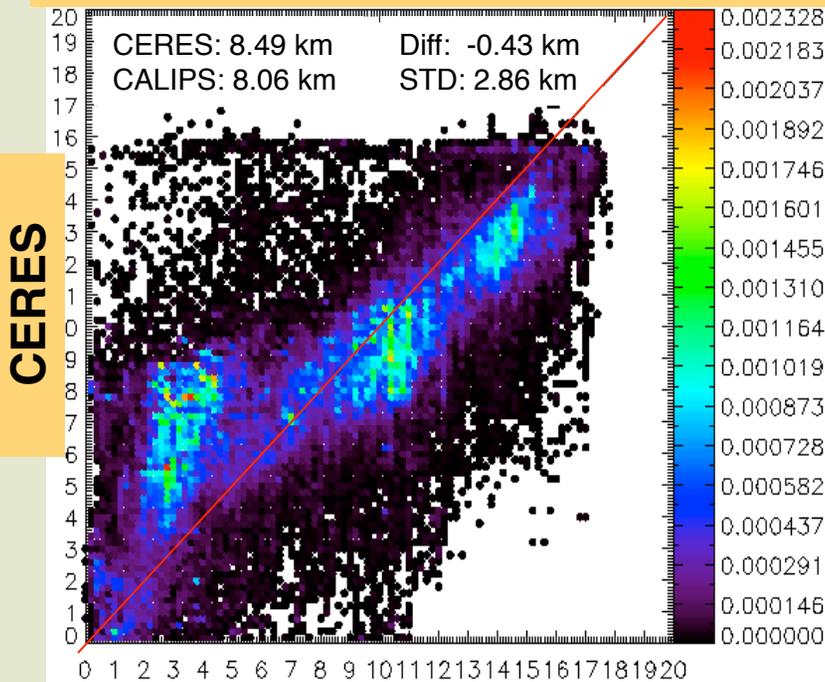
## Terra 200708, Day Time, Cloud Top Height Diff



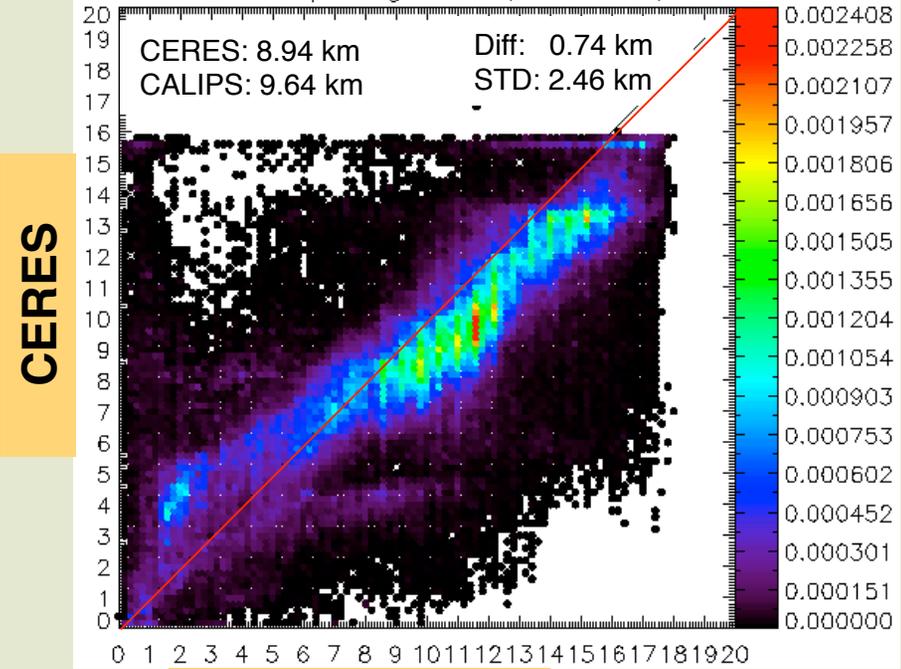
VISST ice clouds higher than CO2 clouds (~0.5 km Ocean, ~1.2 km for Land) ??



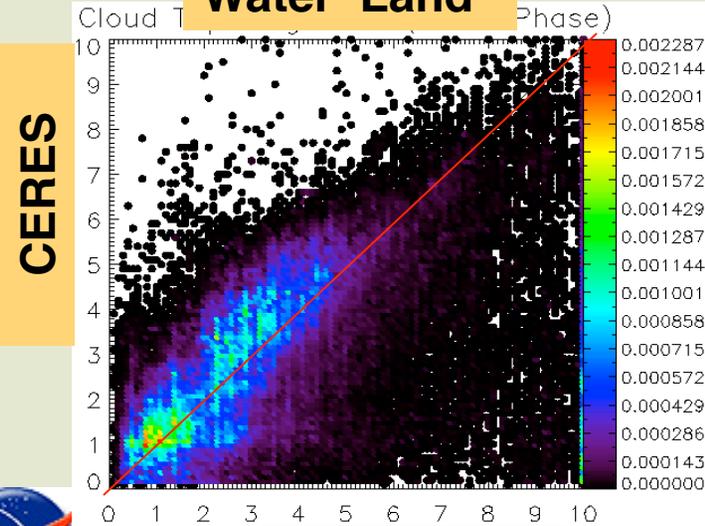
### Cloud Top Height (km): Ice Land



### Cloud Top Height (km): Ice Ocean

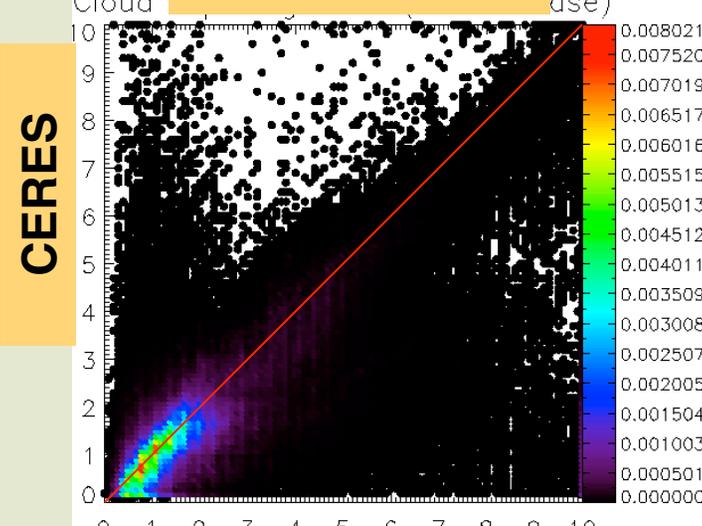


### Water Land



CERES: 2.87 km  
CALIPS: 3.44 km  
**CALIPSO**  
Diff: 0.57 km  
STD: 2.52 km

### Water Ocean

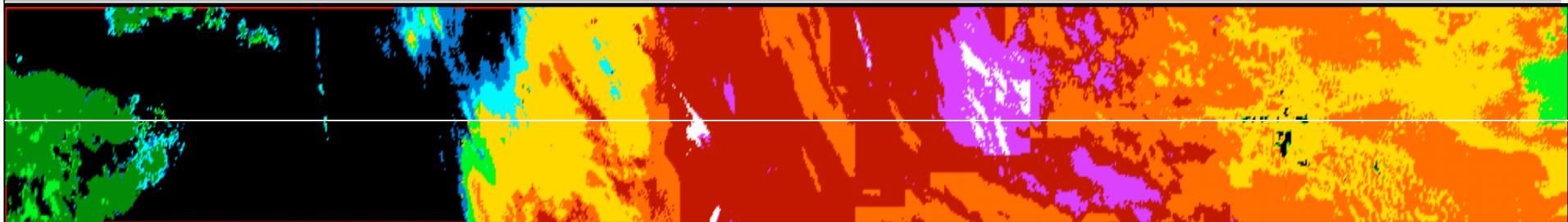
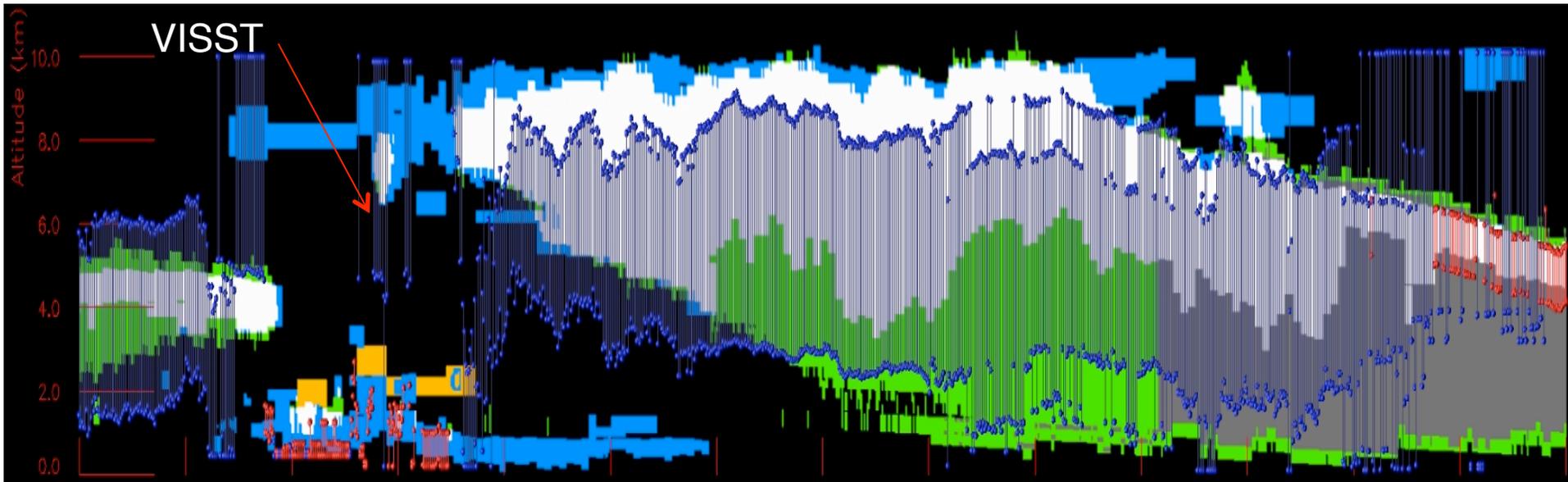


CERES: 1.66 km  
CALIPS: 2.12 km  
**CALIPSO**  
Diff: 0.46 km  
STD: 1.74 km

200702  
Single Layer

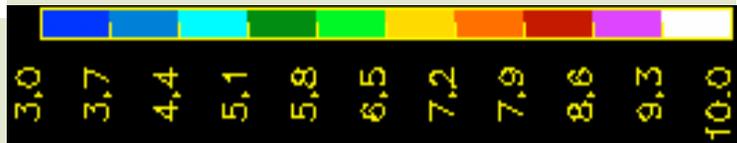
CERES is about 0.5 km higher for ice clouds over land ?

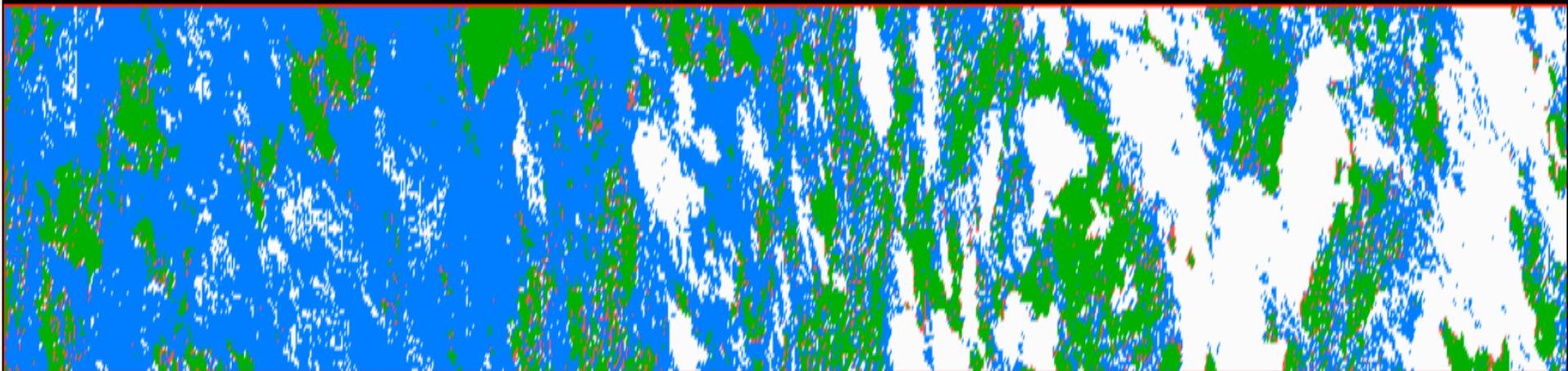
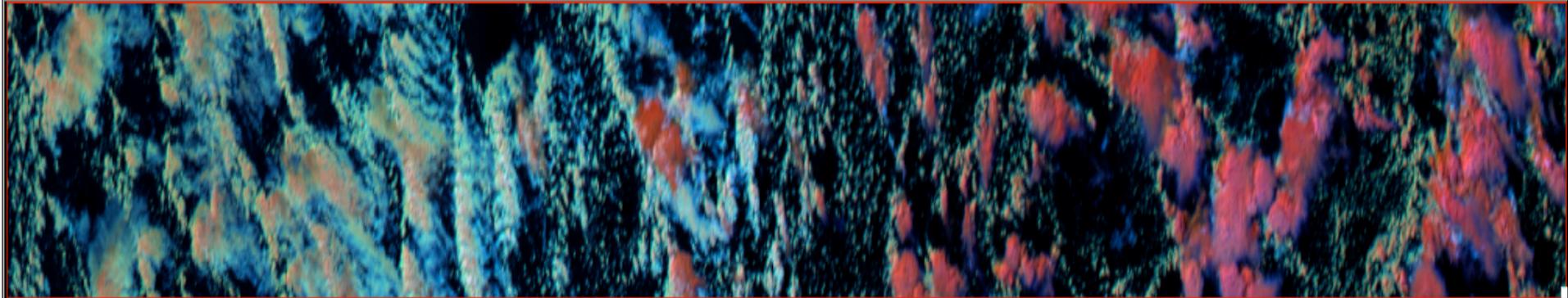
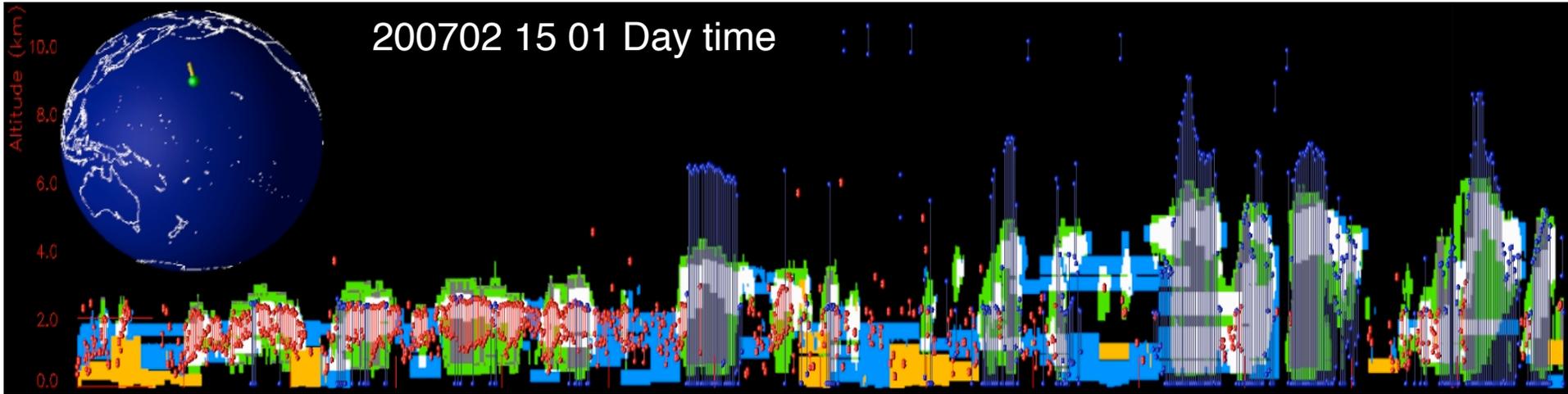




200702 15 01,  
night time

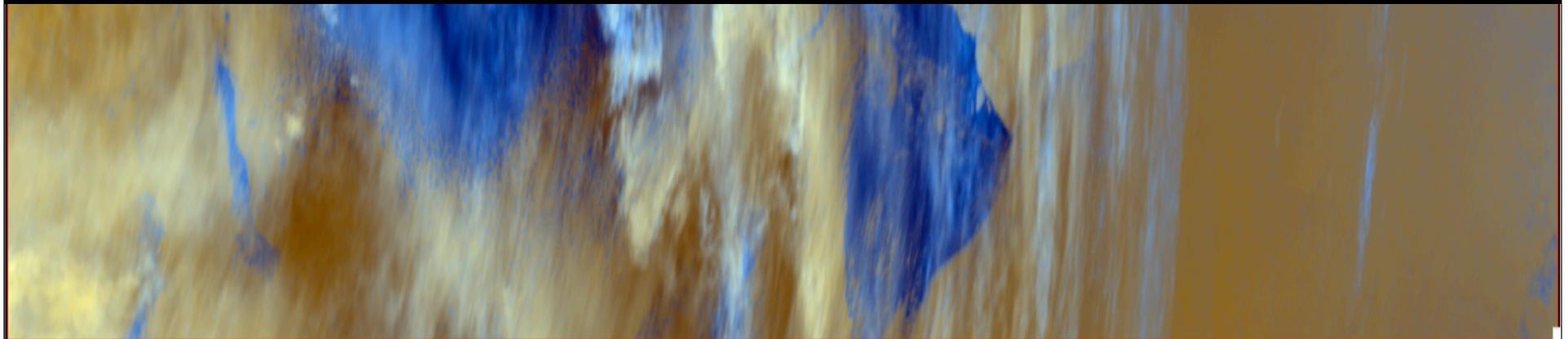
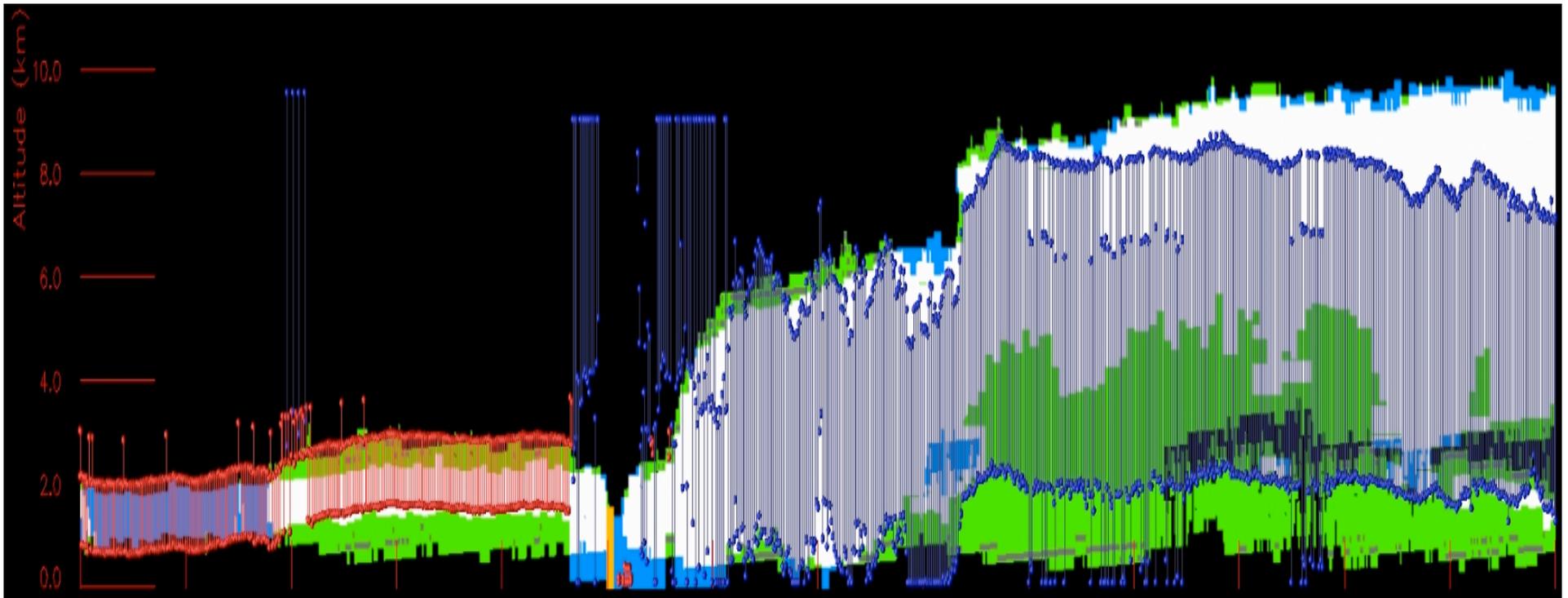
CO2 Height (km)





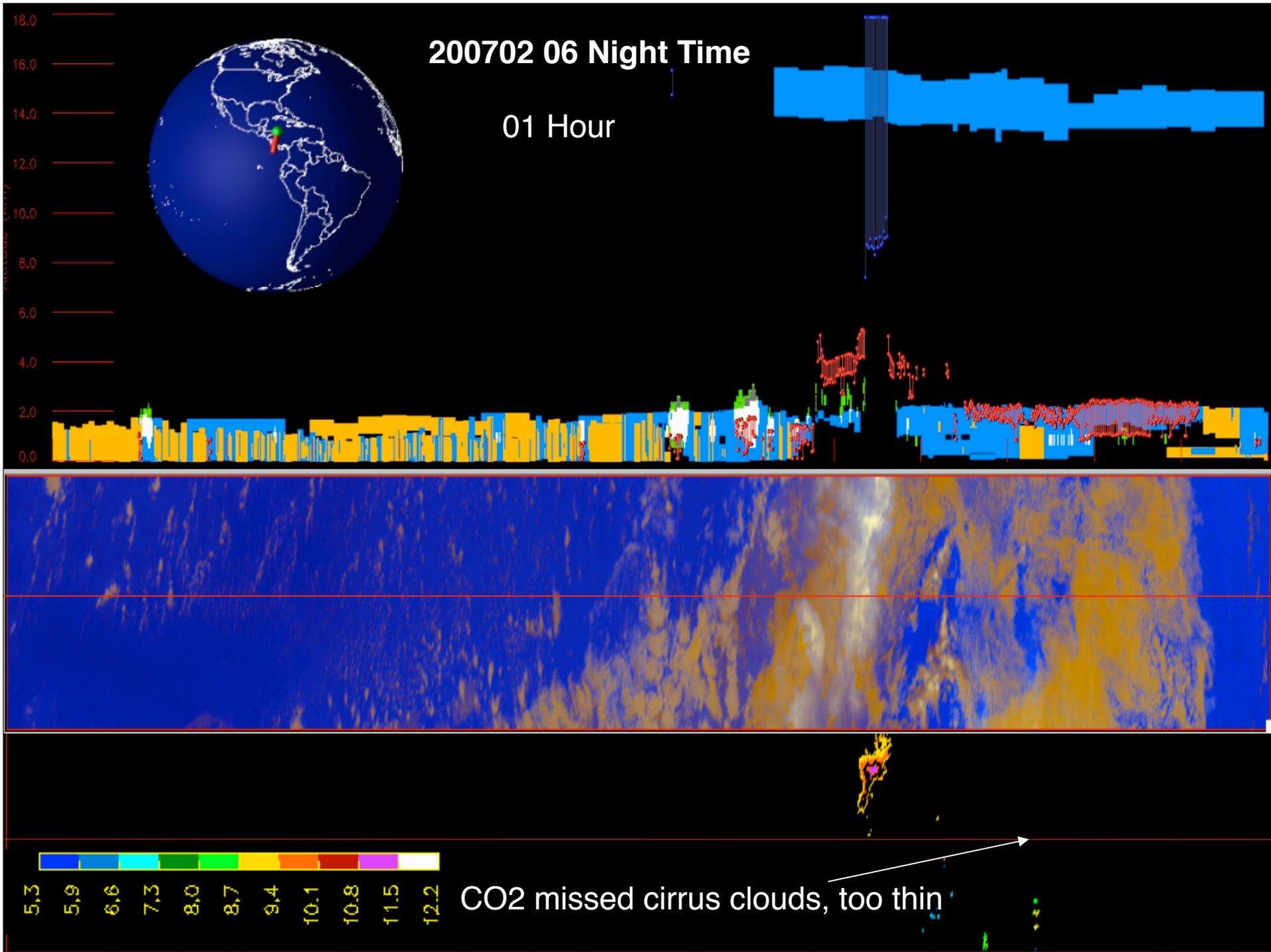
Pink No-Retrieval Spots: Cloud Phase struggles for Cumulus





200702 06 08 Hour, Night Time





# Cloud Thickness



# Results

- For ice clouds

$$\Delta Z = a_0 T_c + a_1 \ln(\tau) + a_2 \ln(IWP)$$

- For water clouds (not used in beta 2)

$$\Delta Z = a_0 T_c + a_1 \ln(\tau) + a_2 Re + a_3 + a_4 T_c \ln(\tau) + a_5 LWP$$

- Different coefficients for each zone over land/ocean
- Adjust fits based on distribution of residuals
- Application: interpolate from tropics to mid-latitudes from tropic fit to midlat fit between 20° and 50°
- Use midlat fits for 50 – 90°

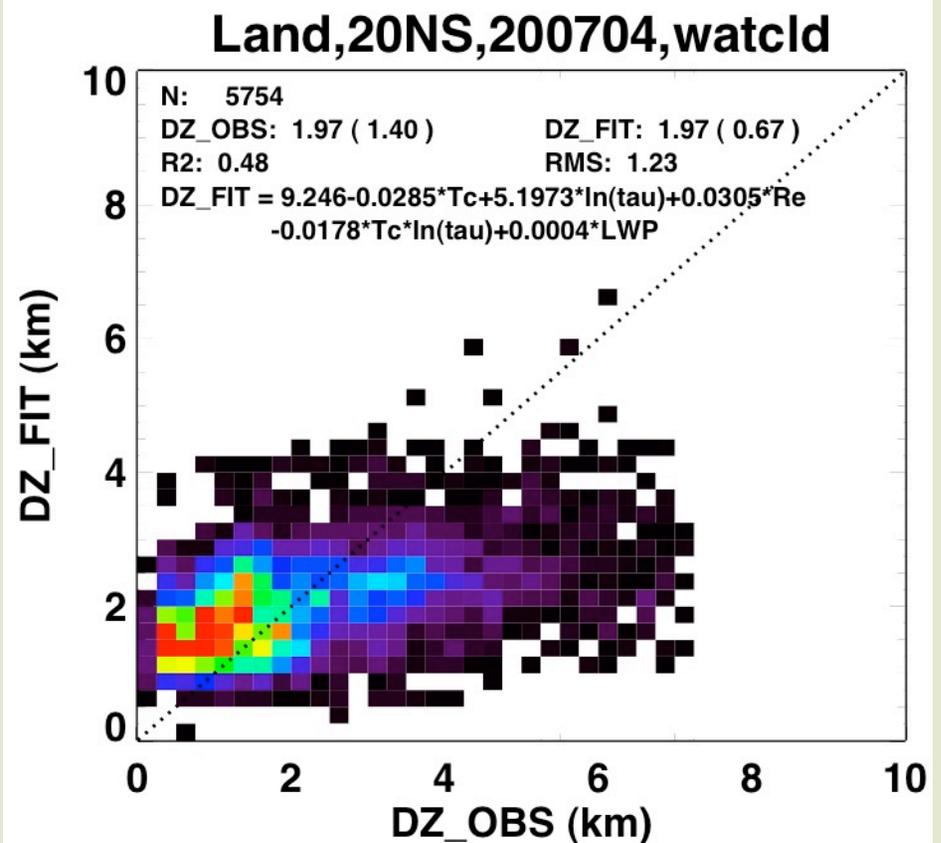
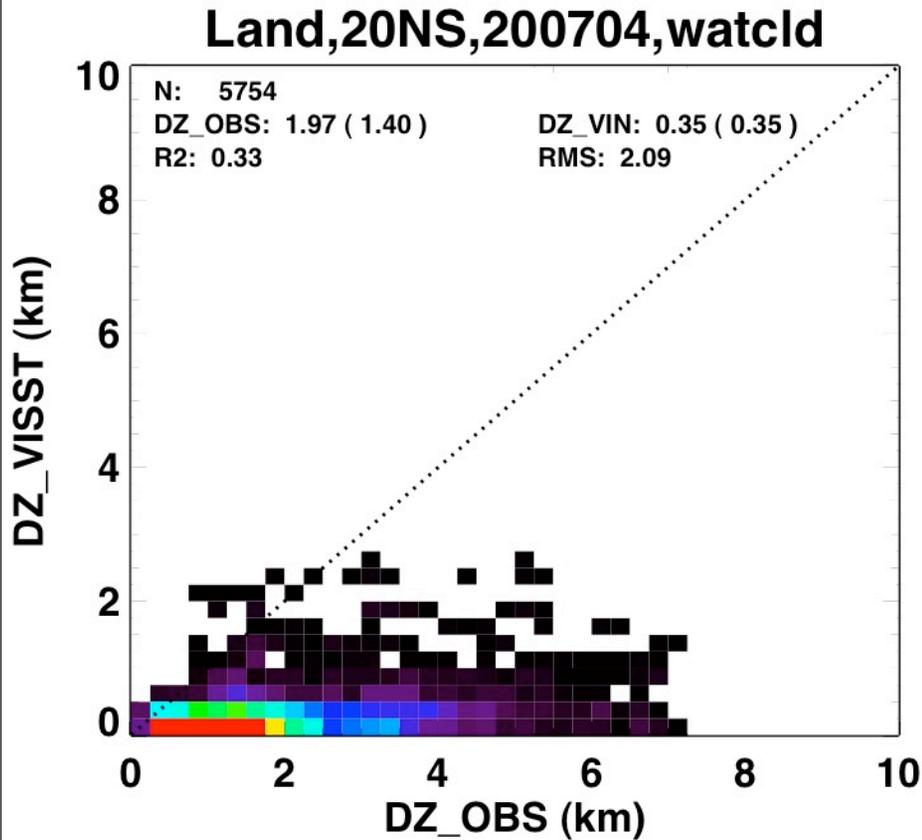


# Water Cloud Over Land (200704)

## Tropics: 20N-20S

Old VISST fit

200704 land tropical fit



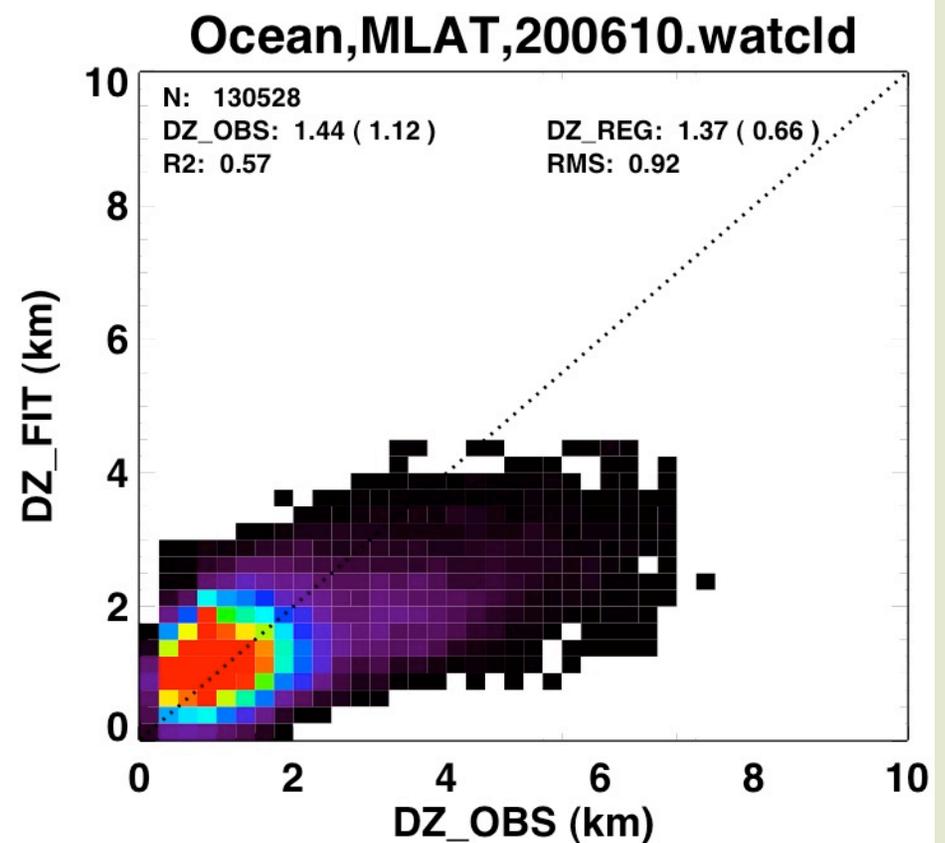
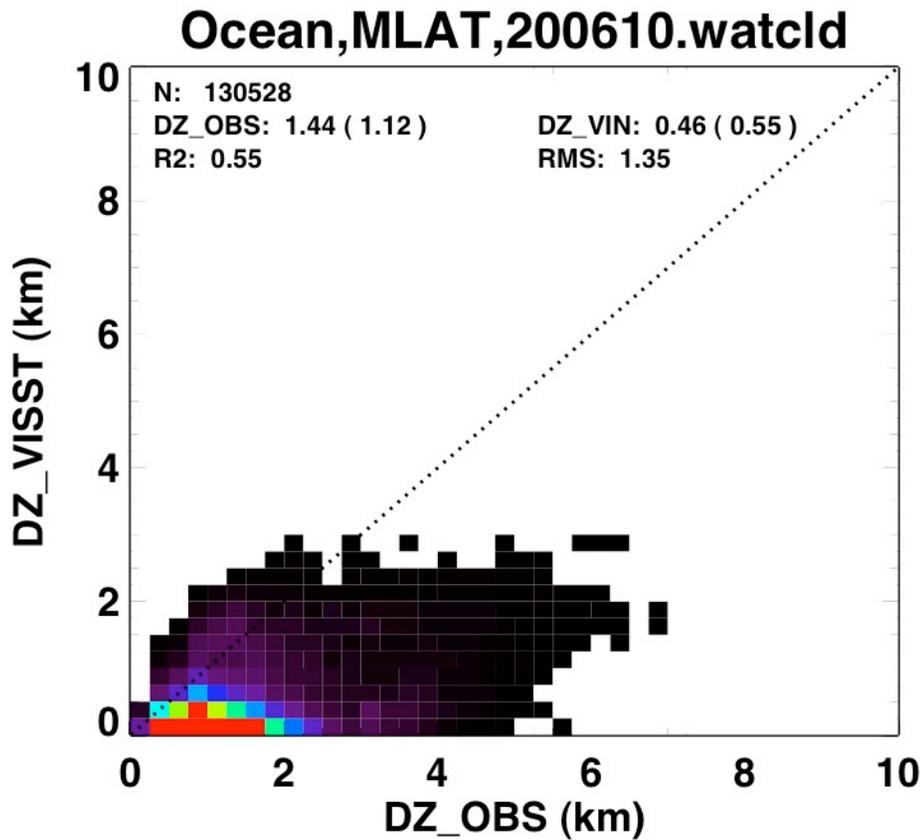
New fit reduces mean bias to 0.0,  
random error by 0.6 km, **but poor distribution**



# Water Cloud Over Ocean (200610): mid latitude: 20N(S)-50N(S)

Old VISST fit

Using 200704 mixed tropical &  
mid-lat fit, plus -0.5 adjustment



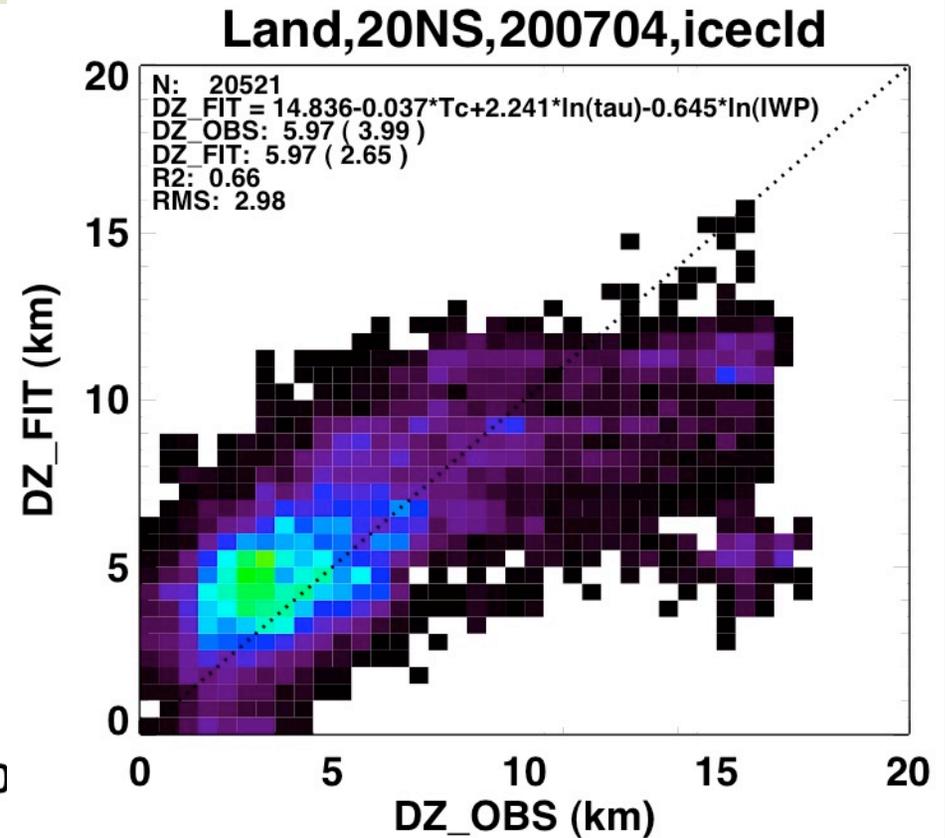
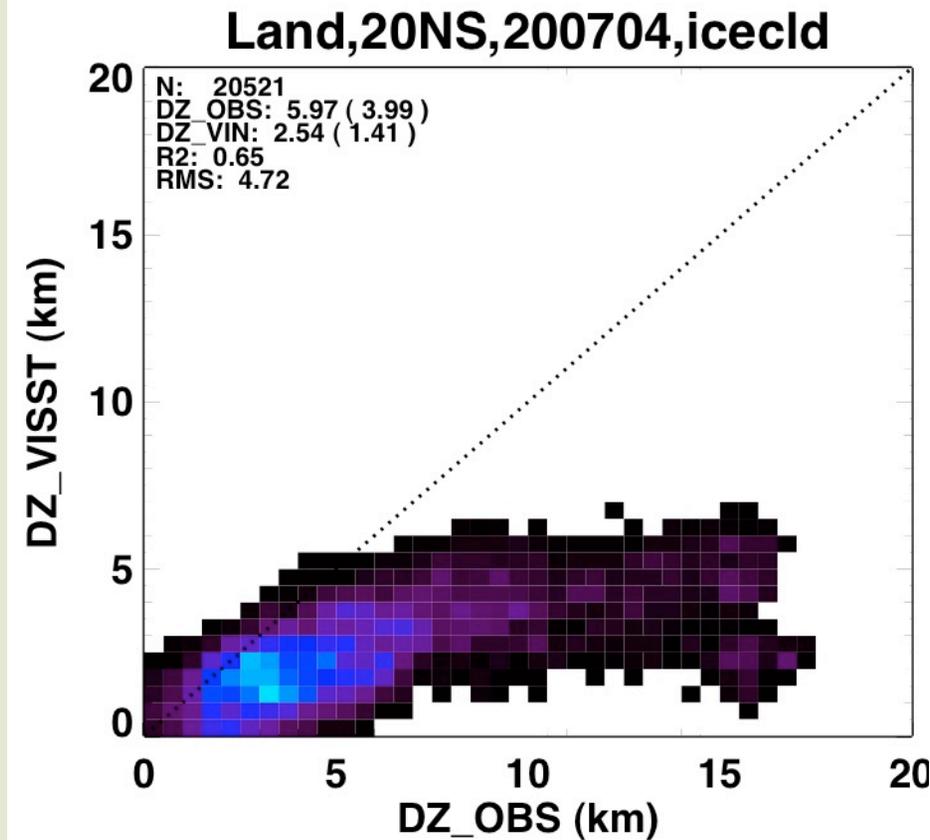
Adjusted fit drops bias by 0.9 km  
Random error by 0.1 km  
Old fit used for Ed3 beta2



# Ice Cloud Over Land (200704) : Tropics: 20N-20S

Old VISST fit

200704 tropical land fit



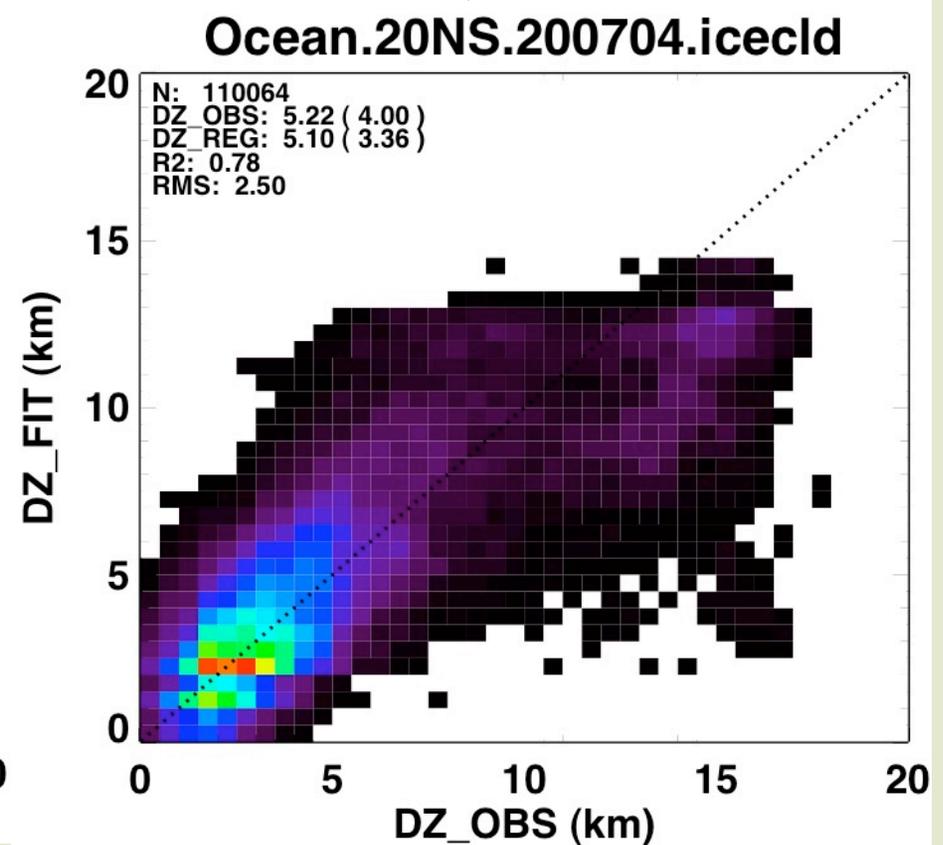
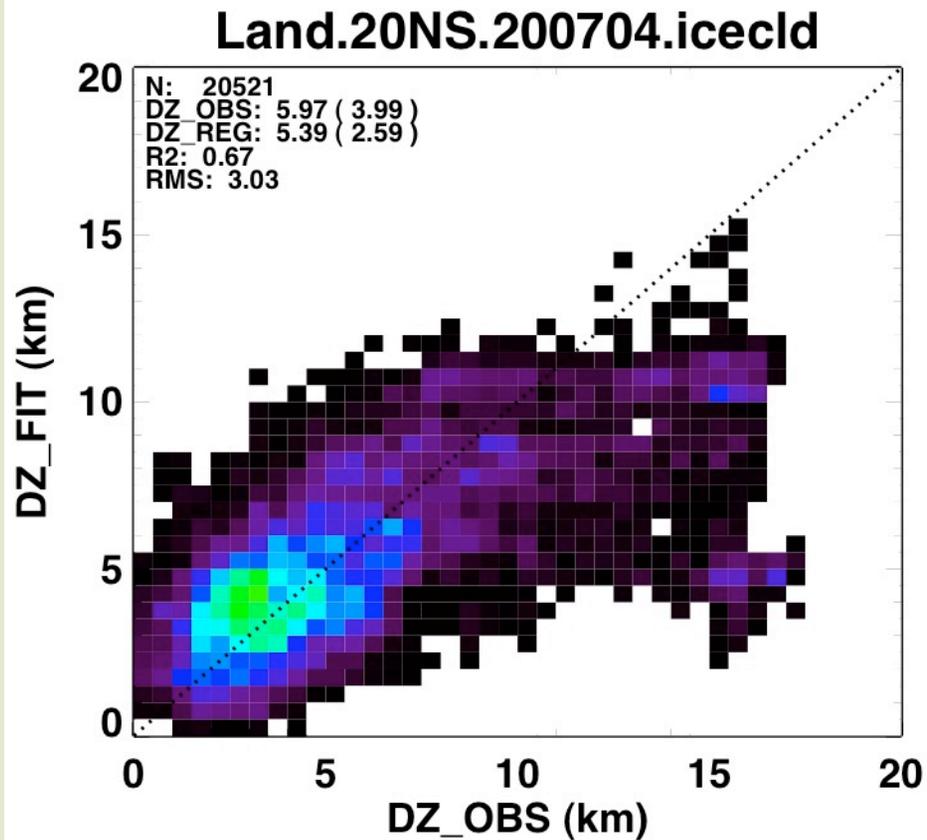
New fit reduces mean bias from 3.4 km to 0.0,  
No random error help, but poor distribution



# Ice Cloud Over Tropics (200704) : adjusted fits: 20N-20S

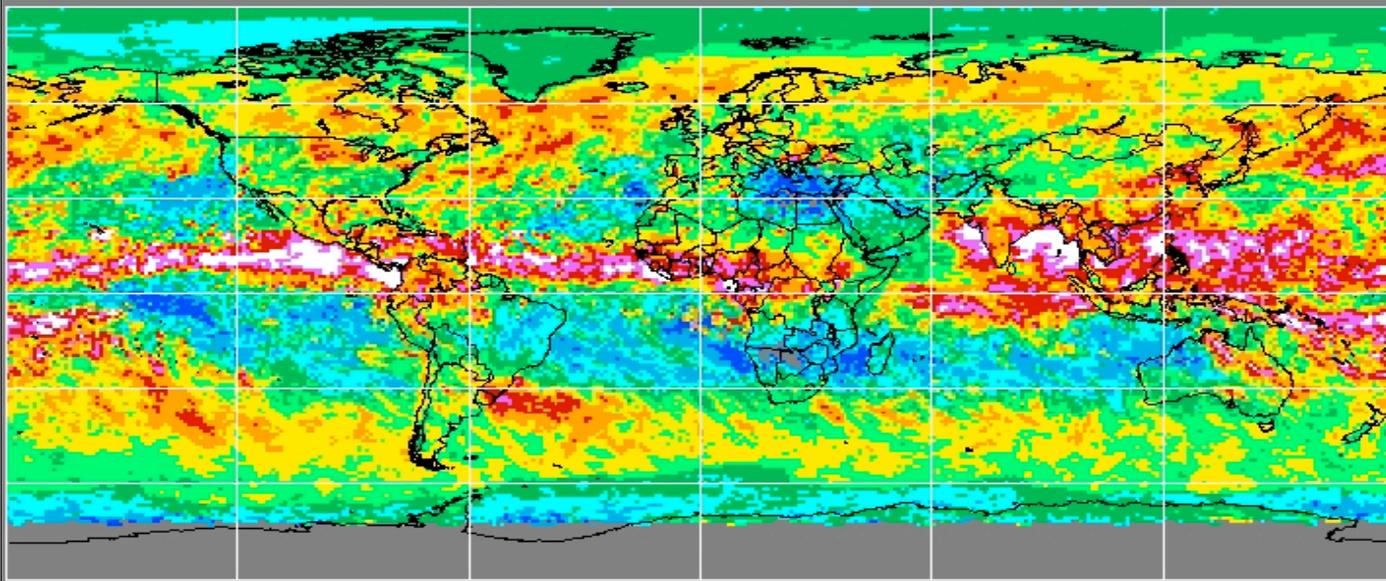
200704 tropical, land fit,  
-0.5 km, if fit >2.0  
+0.5 km, if fit <1.0

200704 Ocean, tropical fit  
3rd ord resid adjustment, if fit >3.7 km  
+0.5 km, if fit <1.0 km



New fits yield better distributions, still miss  
thickest clouds

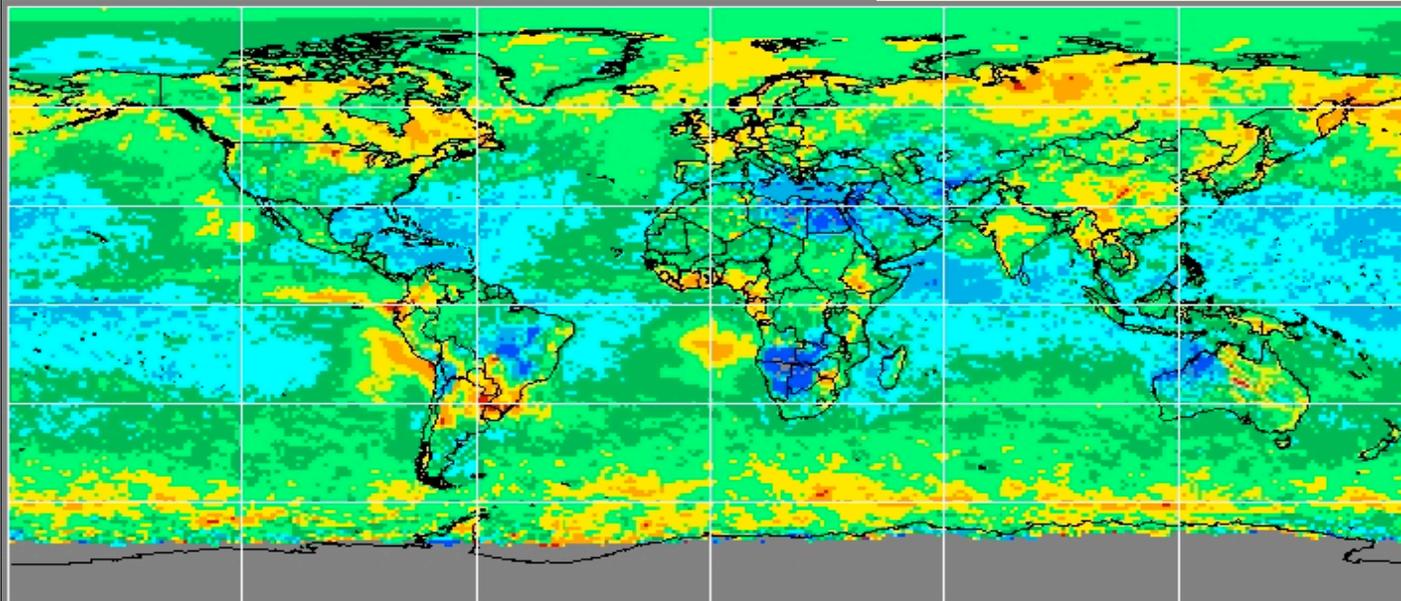




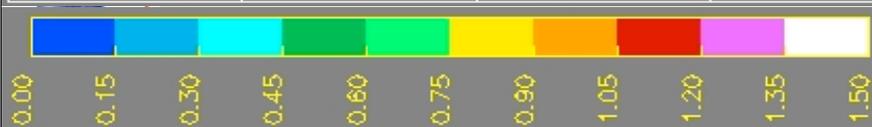
**Ice Clouds**



**200708 Terra, Day Time  
Cloud Thickness**

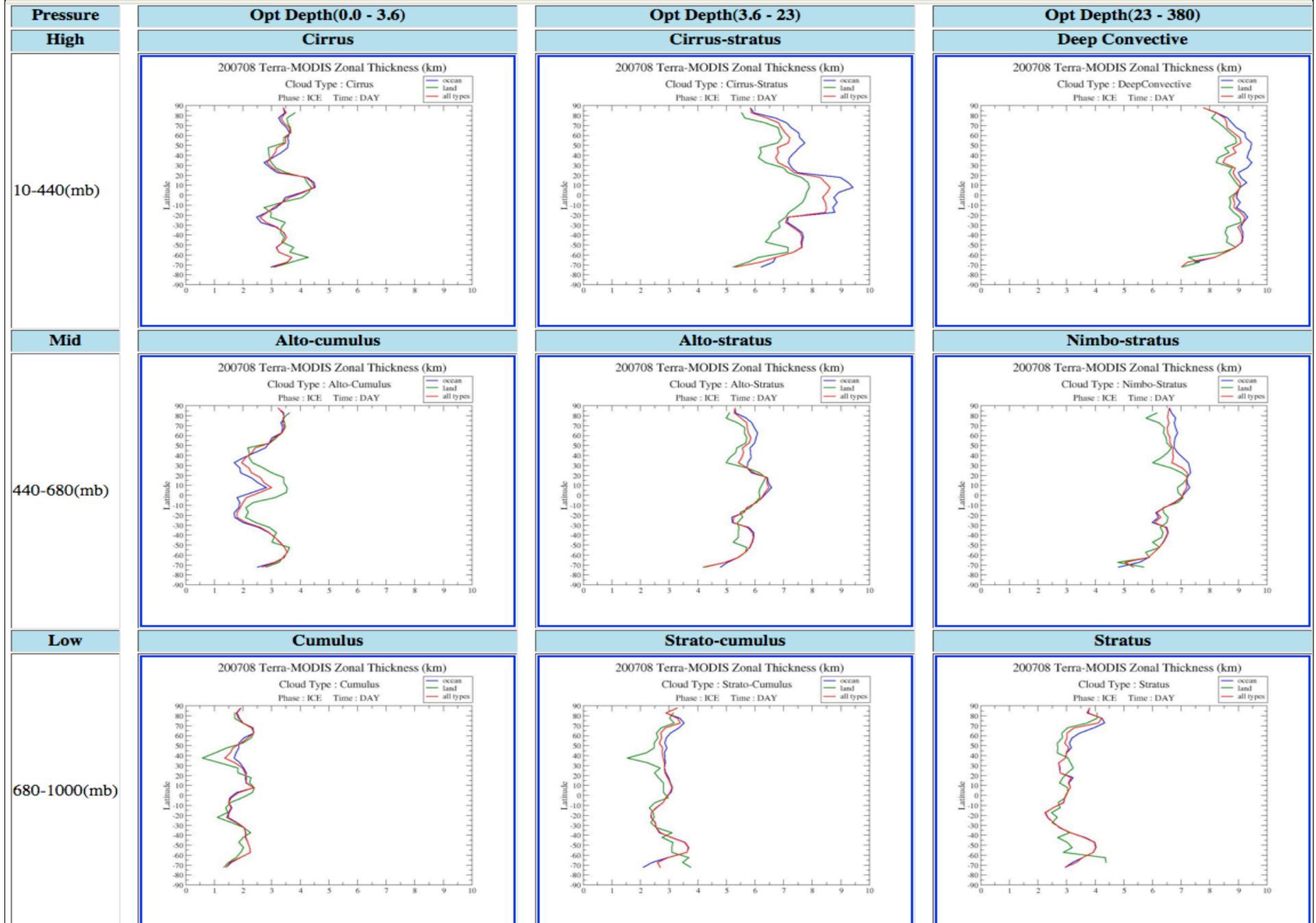


**Water Clouds**

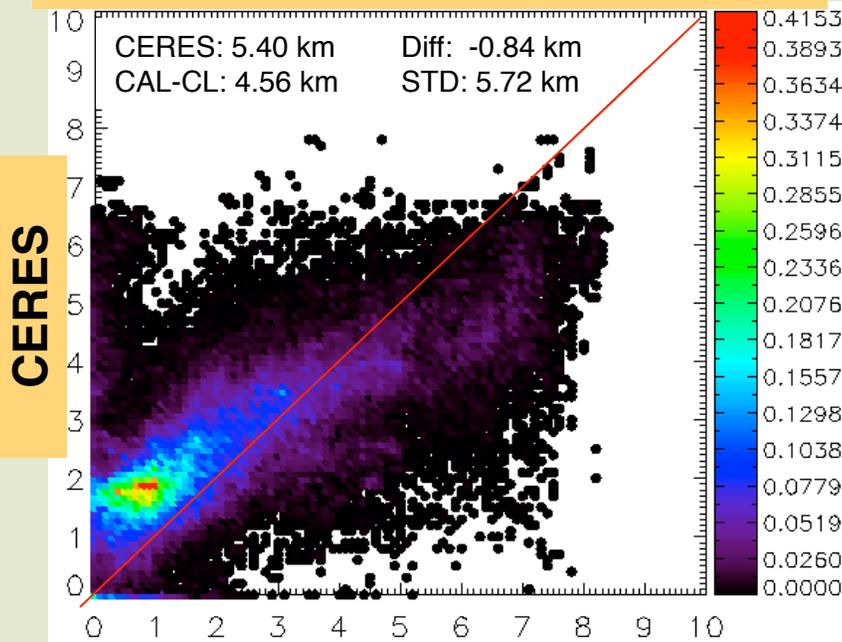


# Terra 200708 CERES ISCCP Cloud Thickness

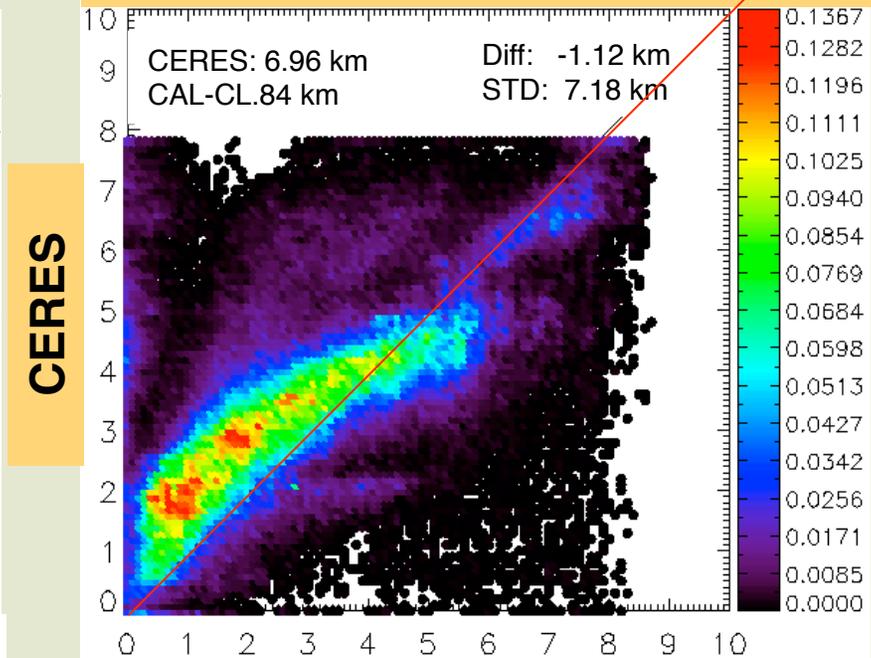
## Ice Clouds, Day Time



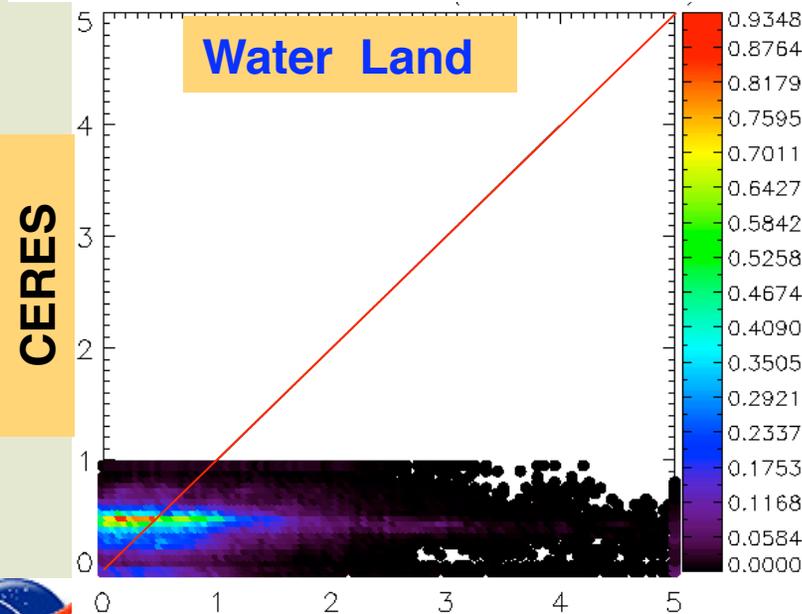
### Cloud Thickness (km): Ice Land



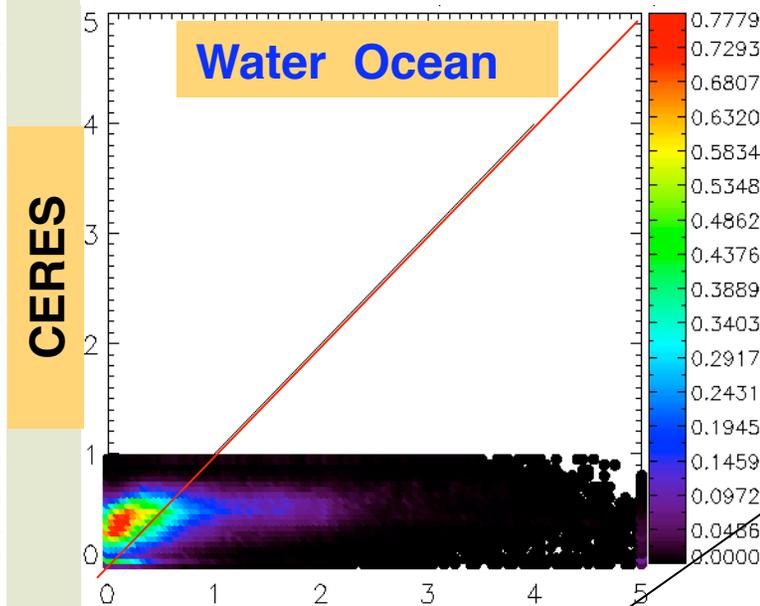
### Cloud Thickness (km): Ice Ocean



### Water Land



### Water Ocean



200702  
Single Layer

CAL-CL:  
CALIPSO cloud  
top and CloudSat  
Cloud Base with  
no precipitation

CERES: 0.91 km  
CAL-CL: 1.72 km

**CAL-CL**

Diff: 0.81 km  
STD: 1.20 km

CERES: 0.91 km  
CAL-CL: 1.44 km

**CAL-CL**

Diff: 0.53 km  
STD: 1.10 km



# Cloud Optical Depth

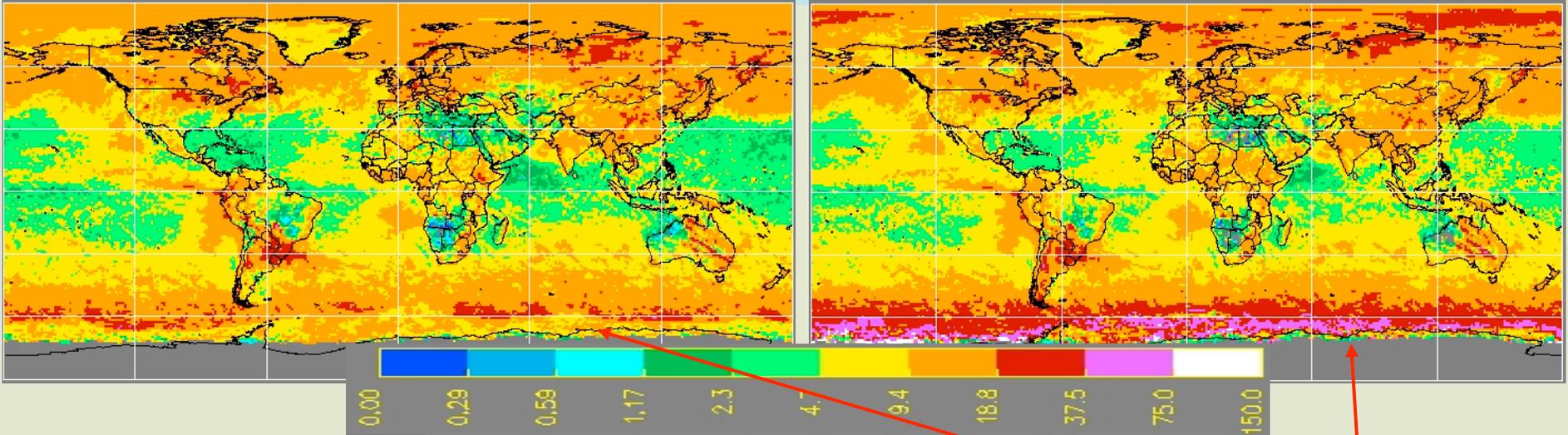
- more cumulus clouds & thin cirrus detected
  - mean tau decreases
- ozone optical depth was overestimated by 13.3% in Ed2
  - tau decreases, most for high SZA
- set maximum tau to 150
  - avg tau increases
- surface reflectance decreased over ocean
  - tau increases for thin clouds
- 2.13  $\mu\text{m}$  used over snow surfaces
  - saturates at  $\tau < 16$  often, less for ice clouds
- false thin clouds thrown out in polar transition
  - avg tau increases



Ed3-Beta2

Terra, 200708, Day, Water, OptDepth

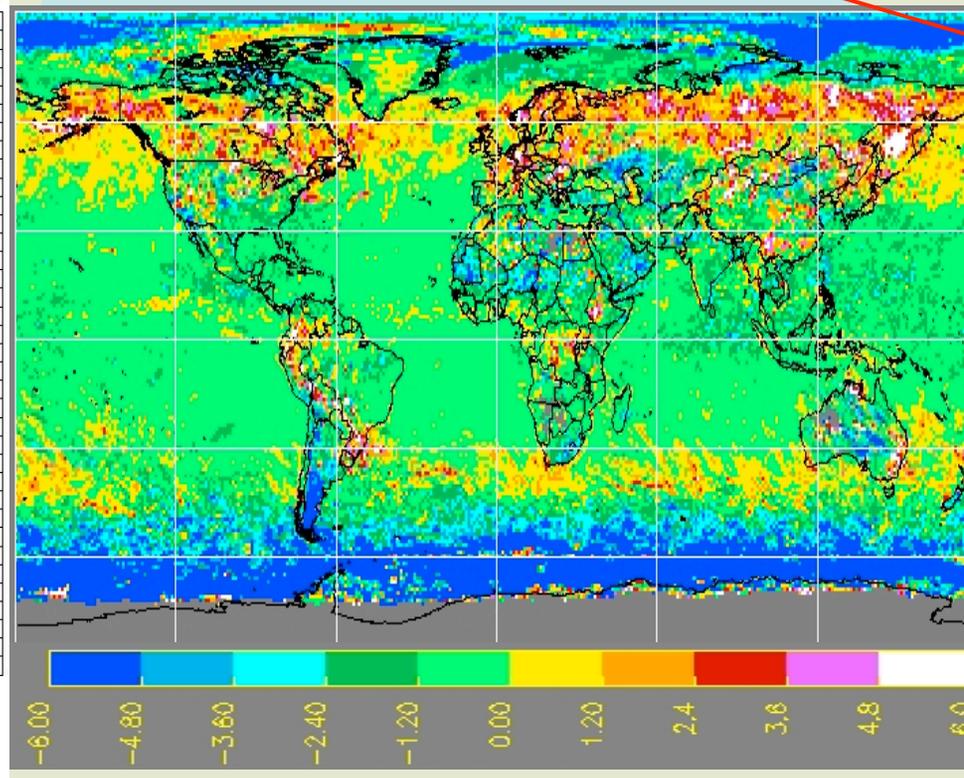
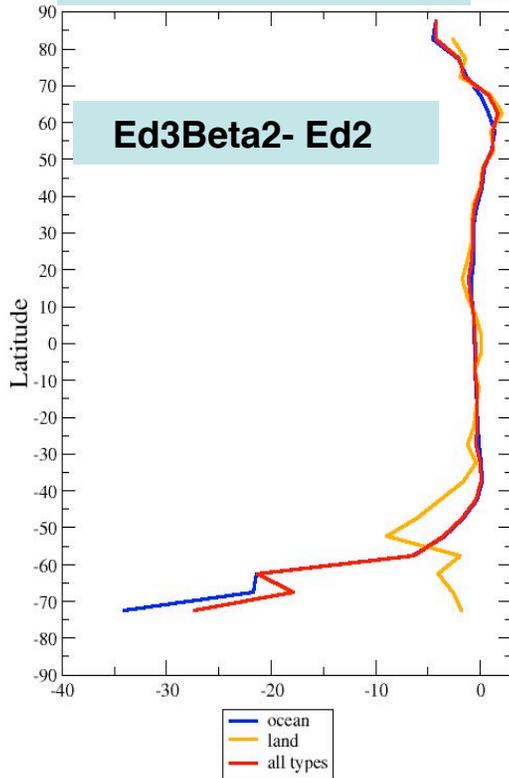
Ed2



OptDep Diff (Water)

: Day

Optical Depth Diff (Water, Ed3Beta2 - Ed2)



Improved with 2.1 corrk for water phase.

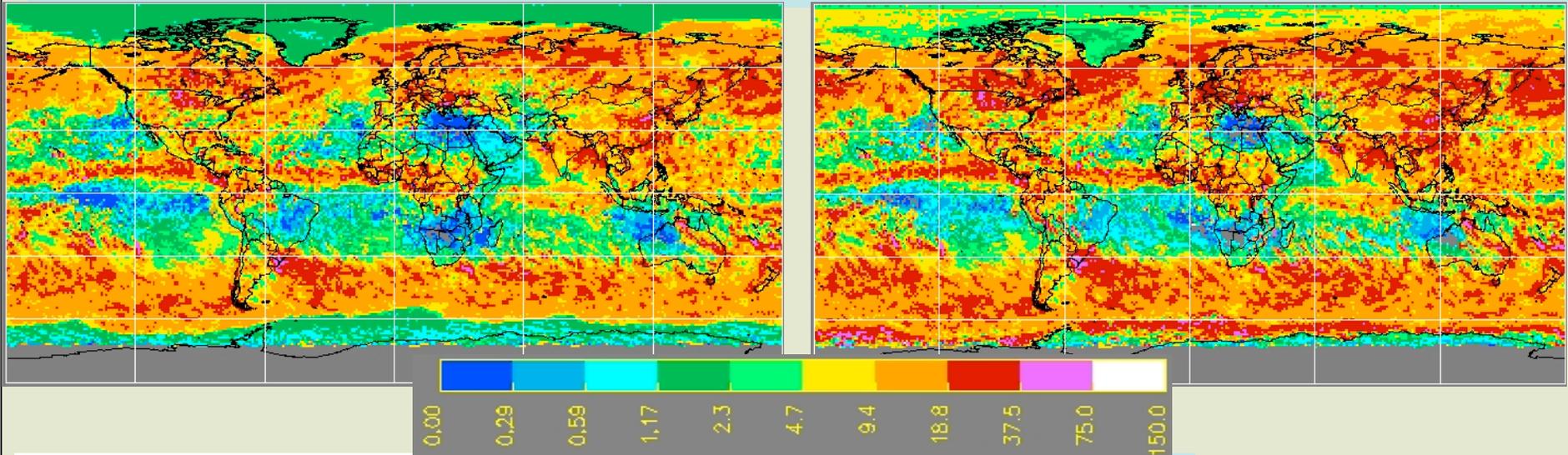
Note:  
Ed3-Beta2: Tau 0-150  
Ed2: Tau 0-128



Ed3-Beta2

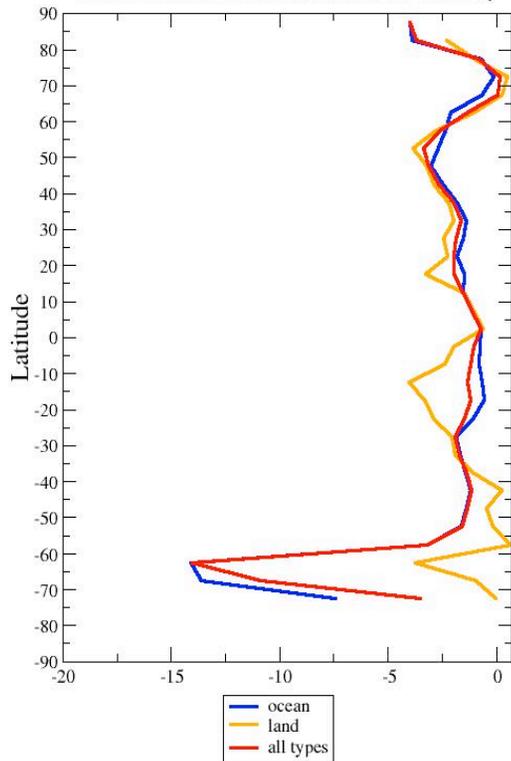
Terra, 200708, Day, Ice OptDepth

Ed2

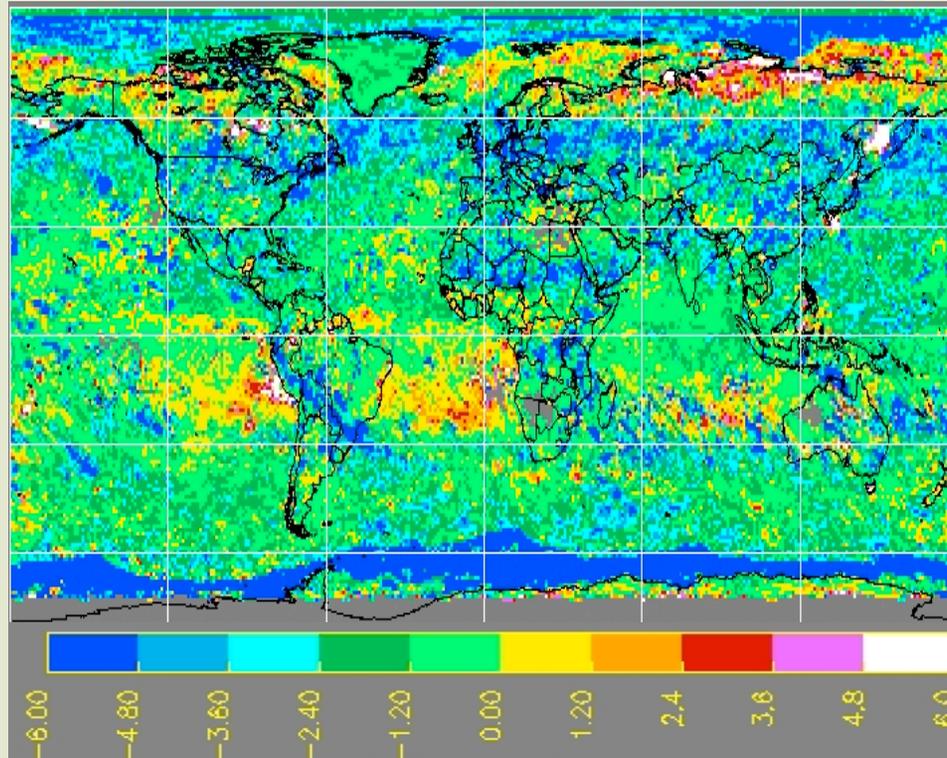


Zonal CloudOptDepth

200708 Terra-MODIS Ed3Beta2-Ed2AQC Ice Phase Day



Optical Depth Diff (Ice, Ed3Beta2 - Ed2)



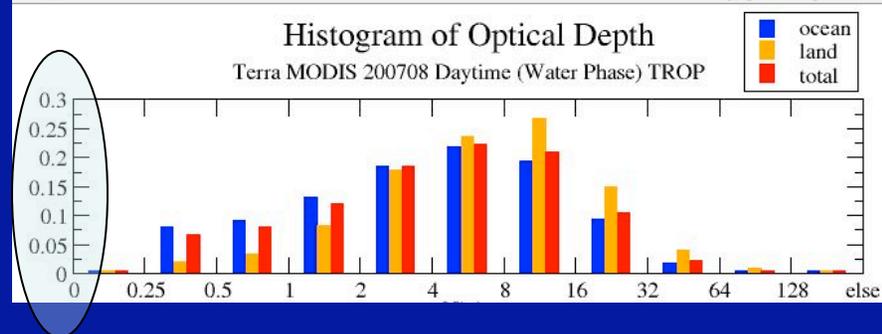
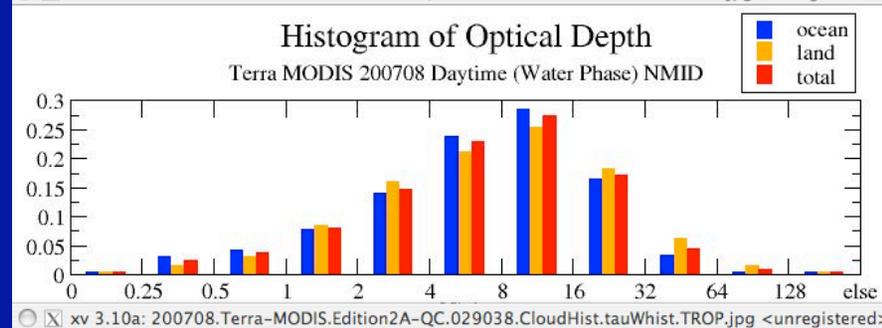
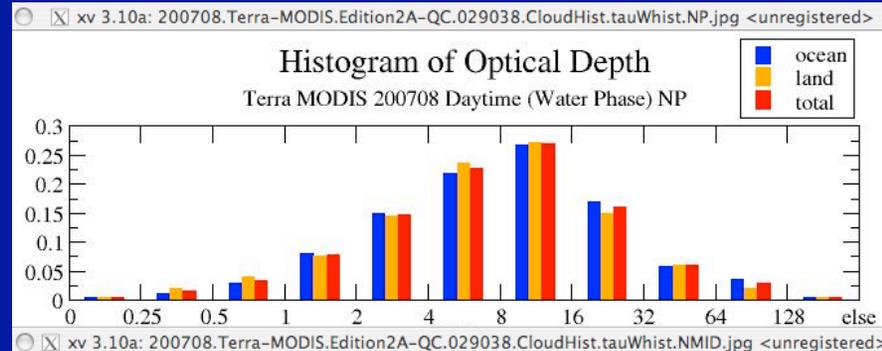
2.1 tau too low for ice?



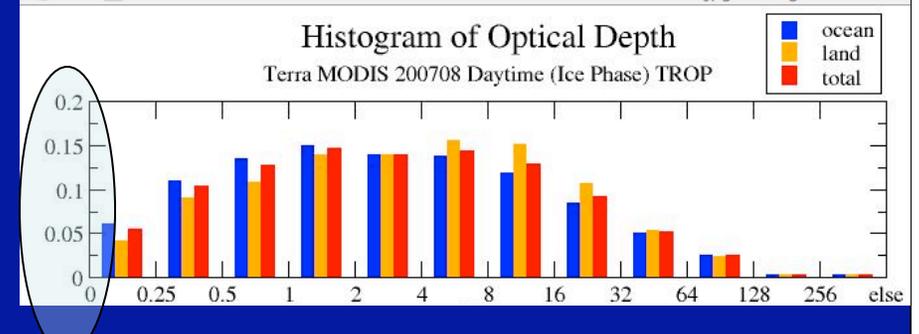
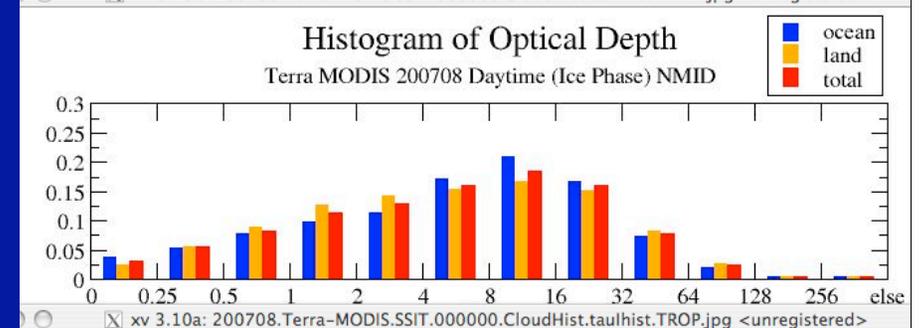
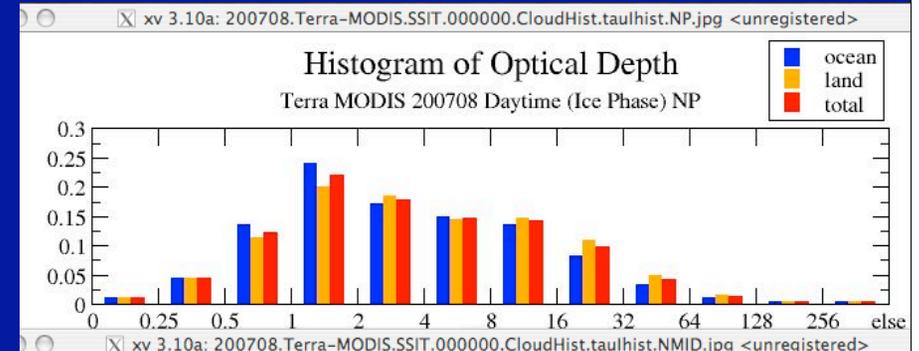
# Ice Cloud Optical Depth Frequencies, Terra, July 2008

## North pole to the Tropics

Ed2



Ed3-beta2

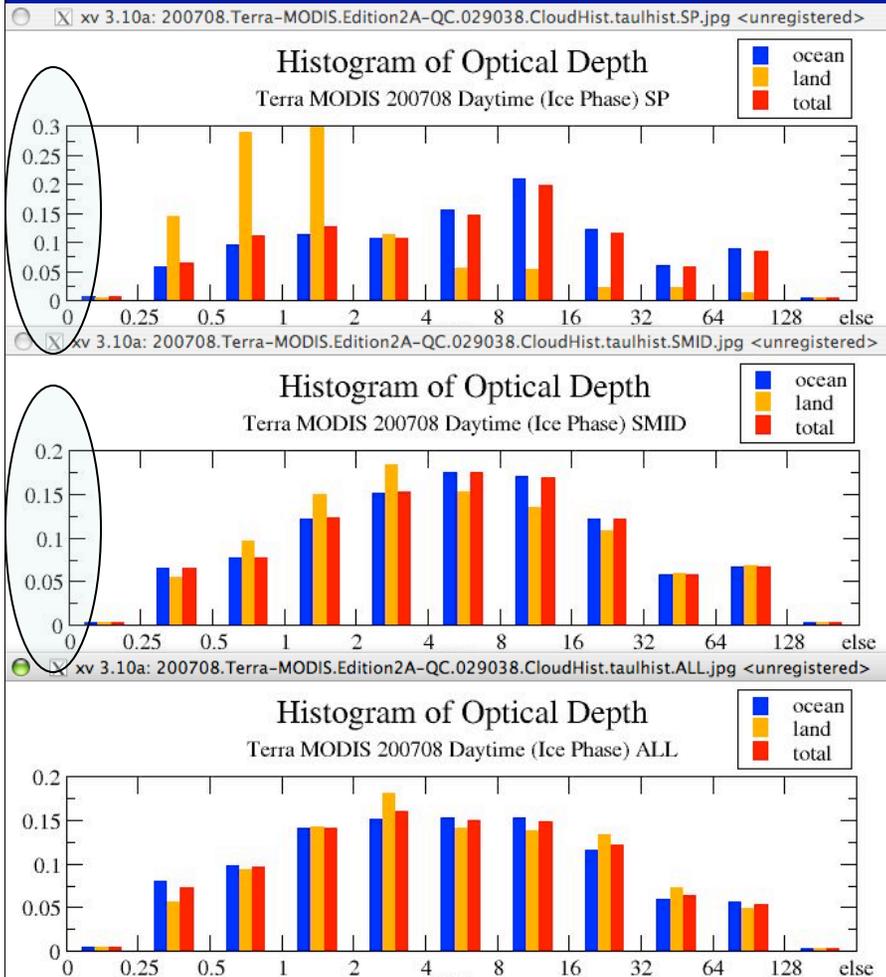


- smaller optical depths more common in Ed3
- more clouds with  $\tau > 32$ , except in Arctic

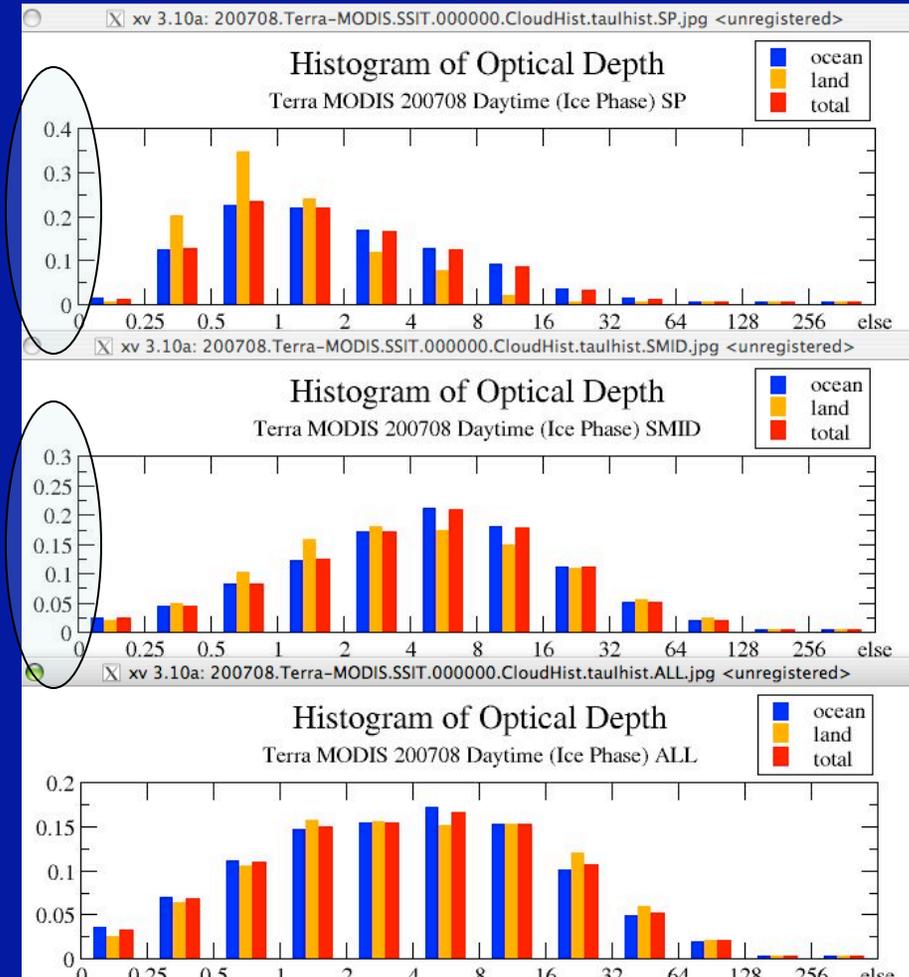
# Ice Cloud Optical Depth Frequencies, Terra, July 2008

## South pole to 20°S, All areas

Ed2

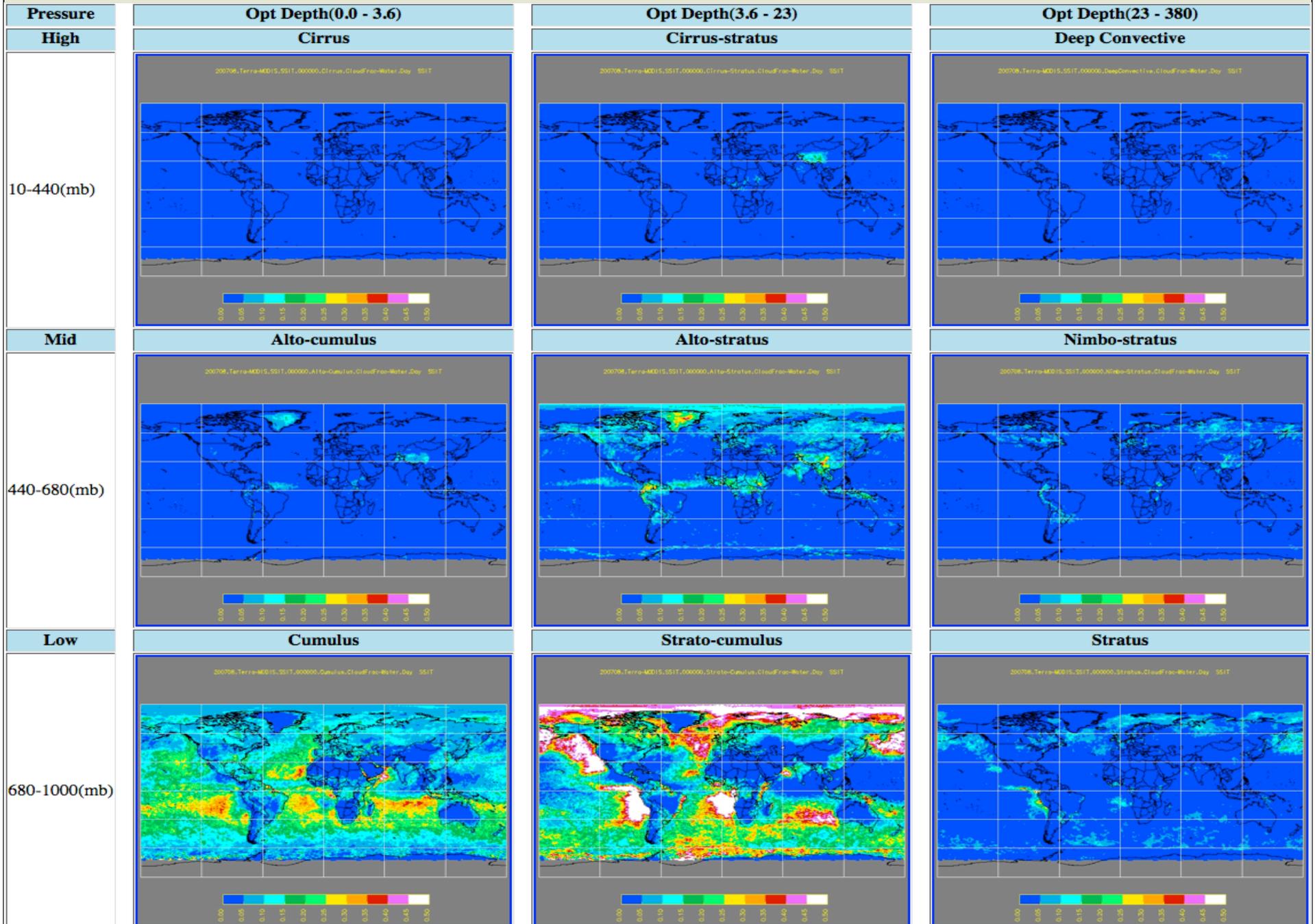


Ed3-beta2



- smaller optical depths more common in Ed3
- $\tau < 0.25$ , not in polar regions

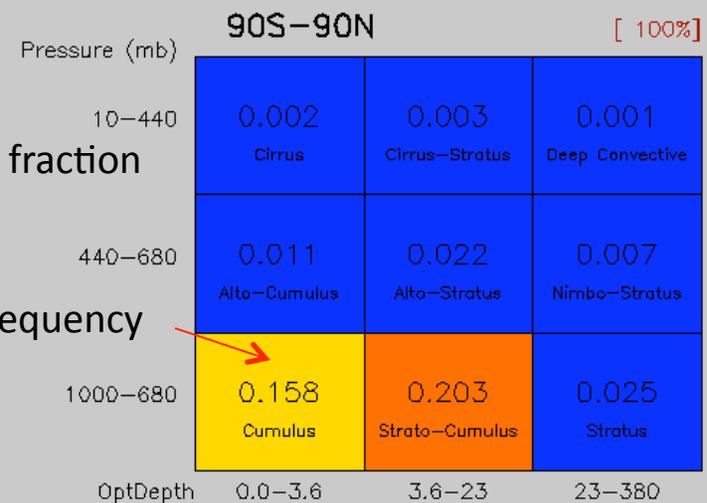
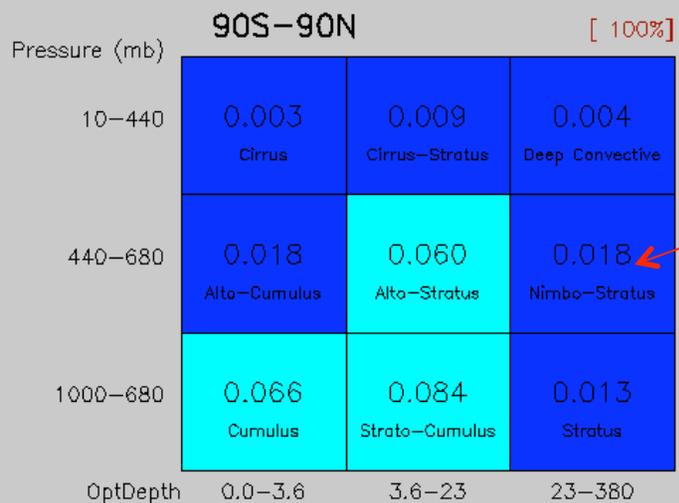
# 200702 Terra, ISCCP Cloud Fraction, Day Time, **Water Clouds**, (note color bars 0—0.5)



# 200708 Terra, CERES ISCCP Cloud Fraction, Day Time, **Water** Clouds (Ed3-Beta2)

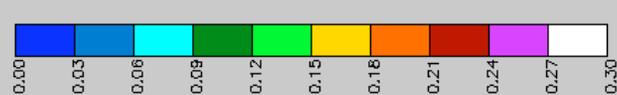
200708 ISCCP Global Averaging of CloudFrac  
**Water Clouds Over Land**

200708 ISCCP Global Averaging of CloudFrac  
**Water Clouds Over Ocean**

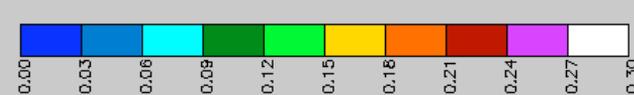


color: cloud fraction

number: frequency



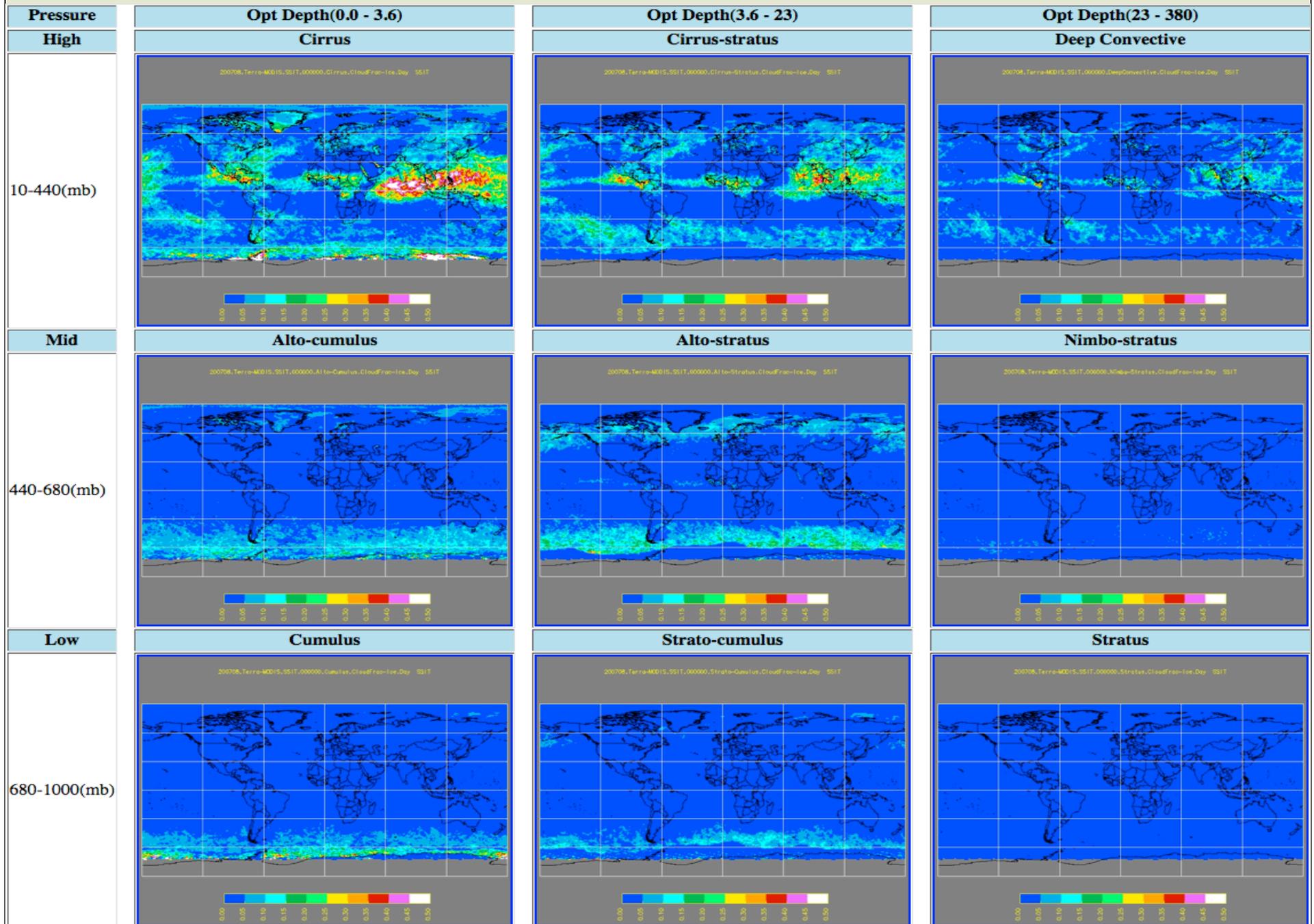
GLOBAL Cloudy PIX  
 [ 112763416 ]  
 GLOBAL Clear PIXE  
 [ 297583808 ]



GLOBAL Cloudy PIXELS  
 [ 410584032 ]  
 GLOBAL Clear PIXELS  
 [ 541826048 ]



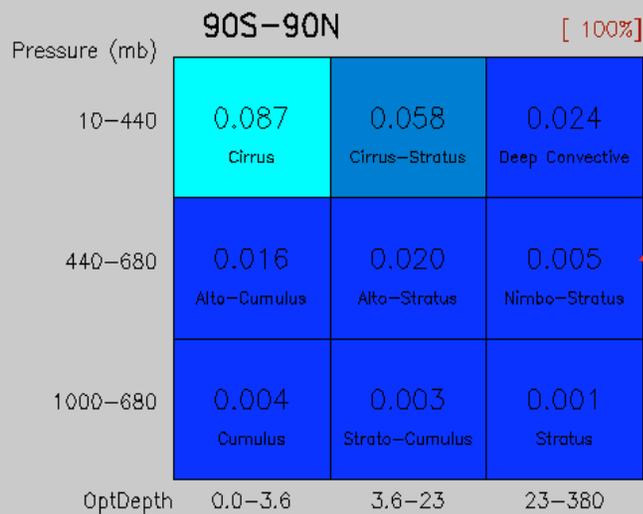
# 200702 Terra, ISCCP Cloud Fraction, Day Time, Ice Clouds (note color bars 0—0.5)



# 200708 Terra, CERES ISCCP Cloud Fraction, Day Time, ICE Clouds (Ed3-Beta2)

200708 ISCCP Global Averaging of CloudFrac

## ICE Clouds Over Land



color: cloud fraction

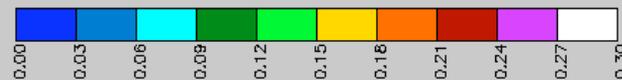
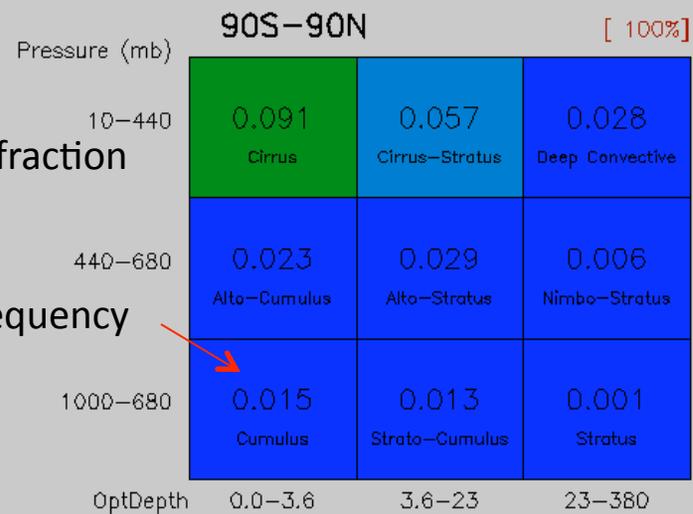
number: frequency



GLOBAL Cloudy PIXELS [ 89004320 ]  
GLOBAL Clear PIXELS [ 321342912 ]

200708 ISCCP Global Averaging of CloudFrac

## ICE Clouds Over Ocean



GLOBAL Cloudy PIXELS [ 251341024 ]  
GLOBAL Clear PIXELS [ 701069056 ]



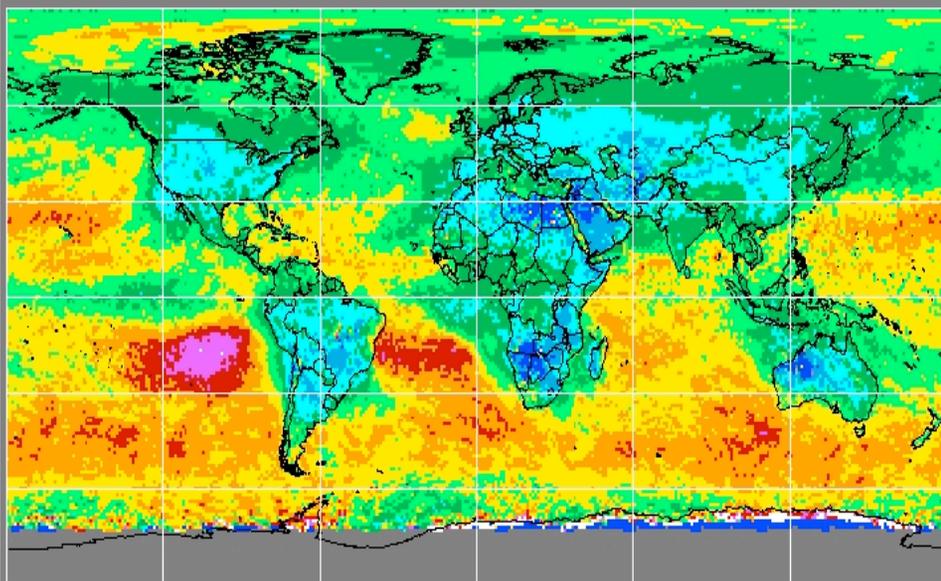
## Cloud Particle Size

- Terra 3.8- $\mu\text{m}$  calibration changed,  $R_e$  increases
- more cumulus clouds & thin cirrus detected
  - mean tau decreases, don't know effect
- ozone optical depth was overestimated by 13.3% in Ed2
  - tau decreases,  $R_e$  increases
- set maximum tau to 150
  - avg tau increases, no impact
- surface reflectance decreased over ocean
  - tau increases for thin clouds,  $R_e$  decreases
- 2.13  $\mu\text{m}$  used over snow surfaces
  - saturates at  $\tau < 16$  often, less for ice clouds,  $R_e$  increases
- false thin clouds thrown out in polar transition
  - avg tau increases, don't know effect

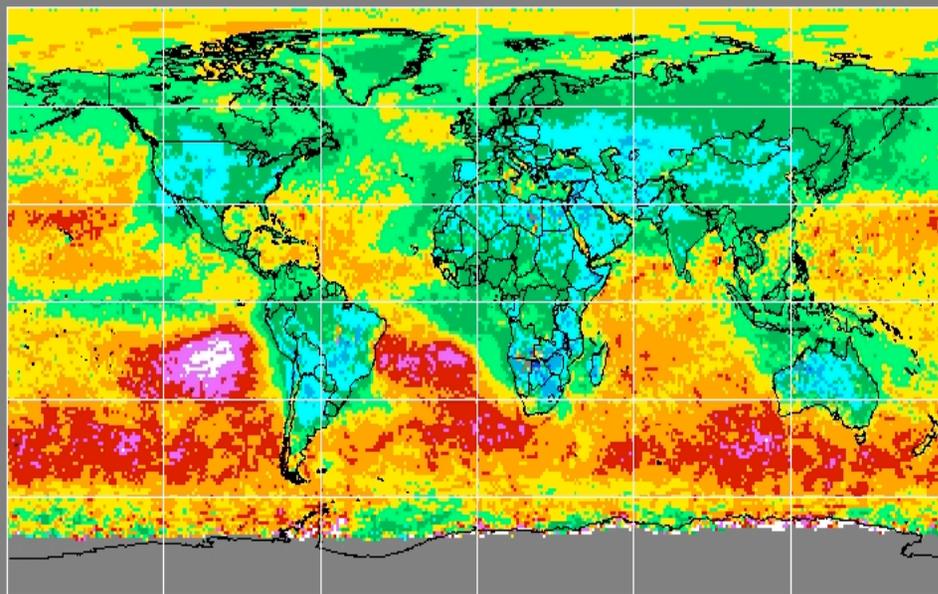


## Water Cloud Reff Averages, Terra, July 2008

Ed2



Ed3-beta2

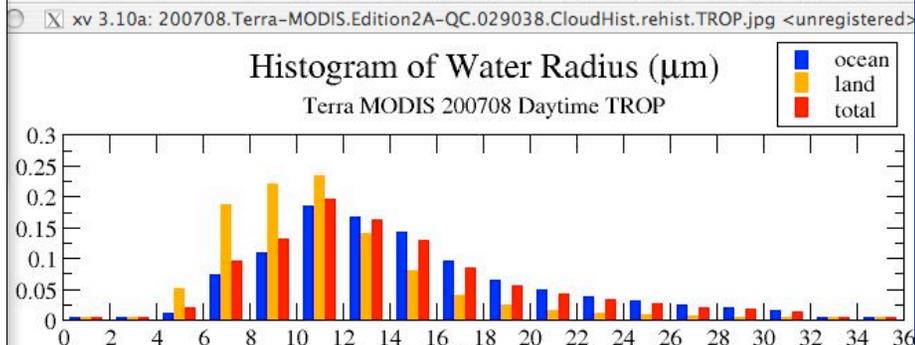
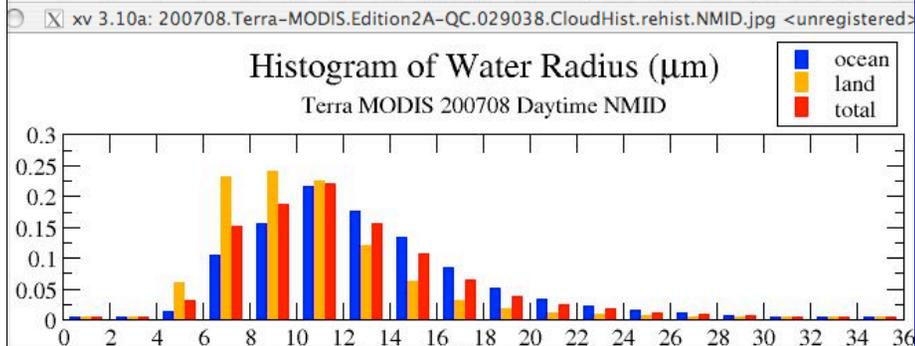
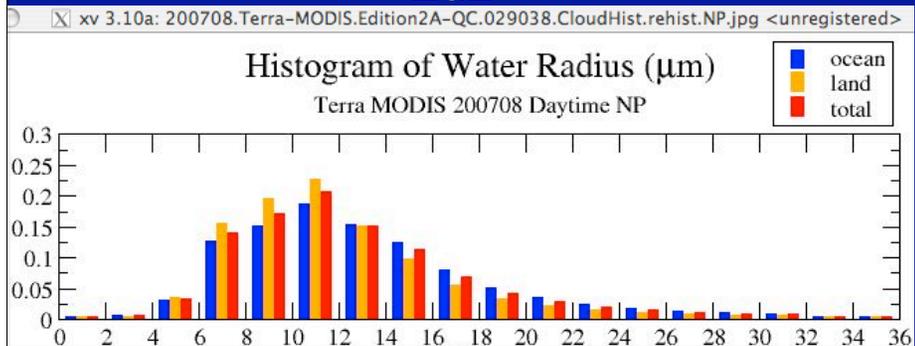


- Re increased from  $13.5 \mu\text{m}$  to  $14.1 \mu\text{m}$  in polar regions
- Re rose from  $13.5 \mu\text{m}$  to  $14.3 \mu\text{m}$  in non-polar regions

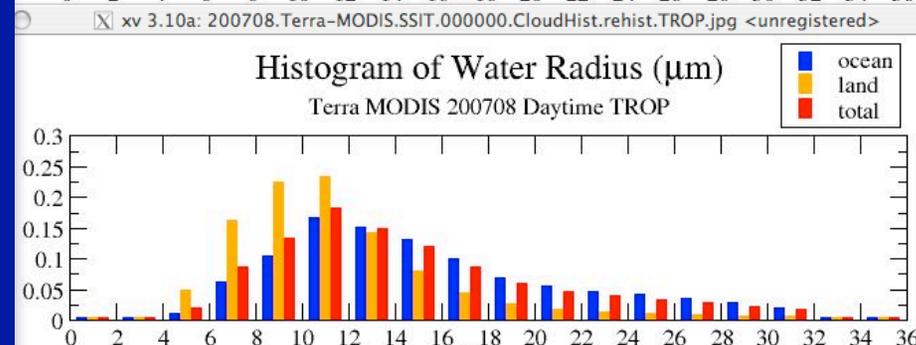
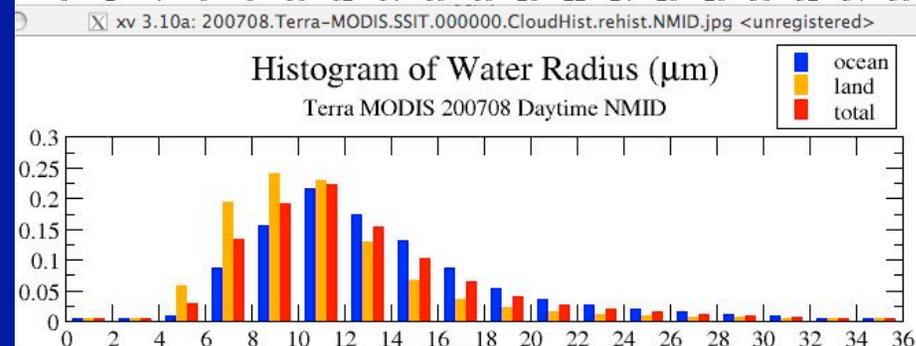
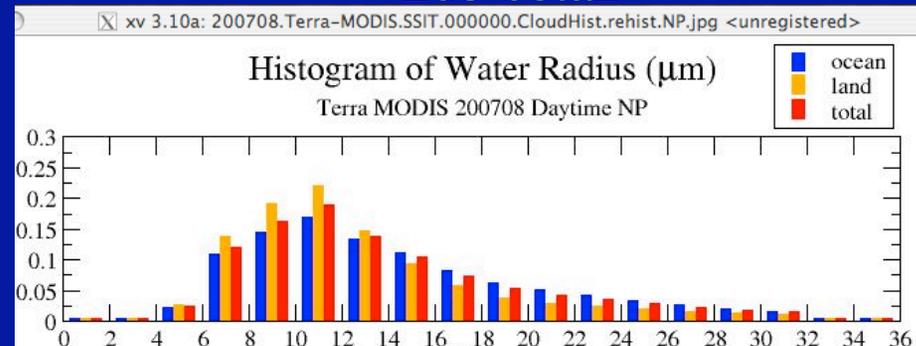
# Water Cloud Reff Frequencies, Terra, July 2008

## North pole to the Tropics

Ed2



Ed3-beta2

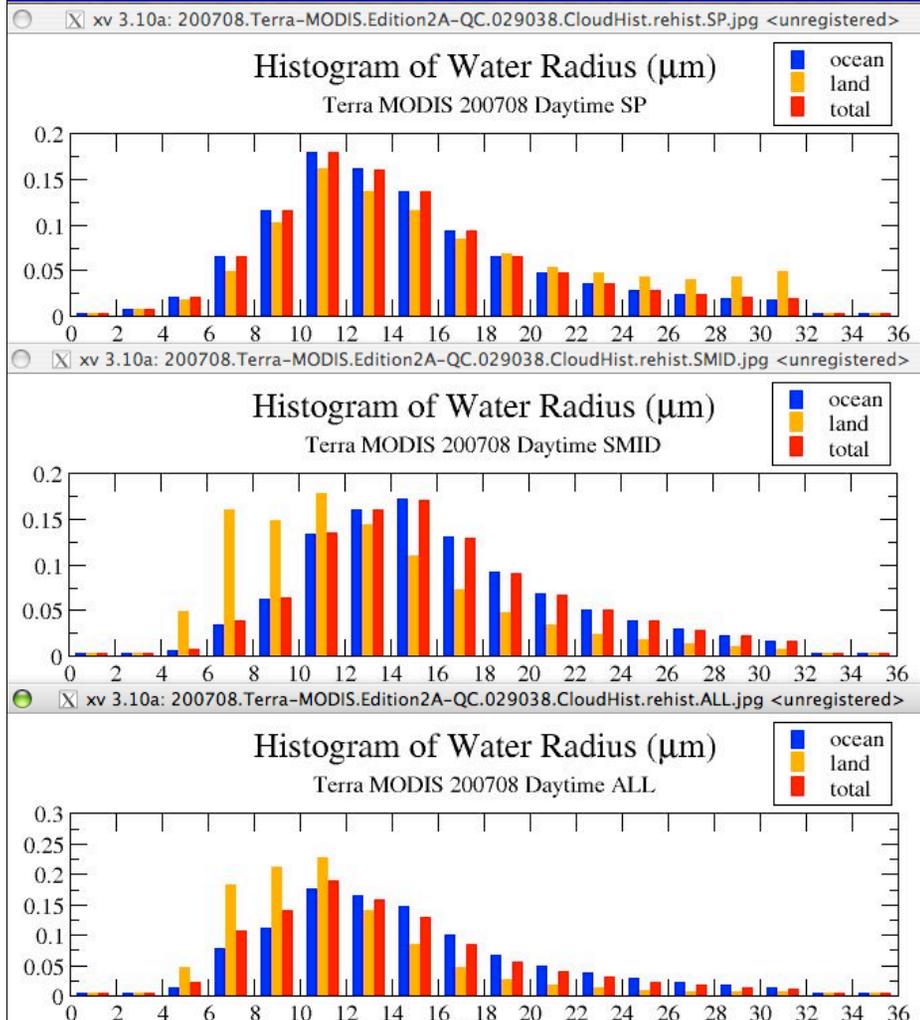


- larger Re more common in Ed3, especially in Arctic

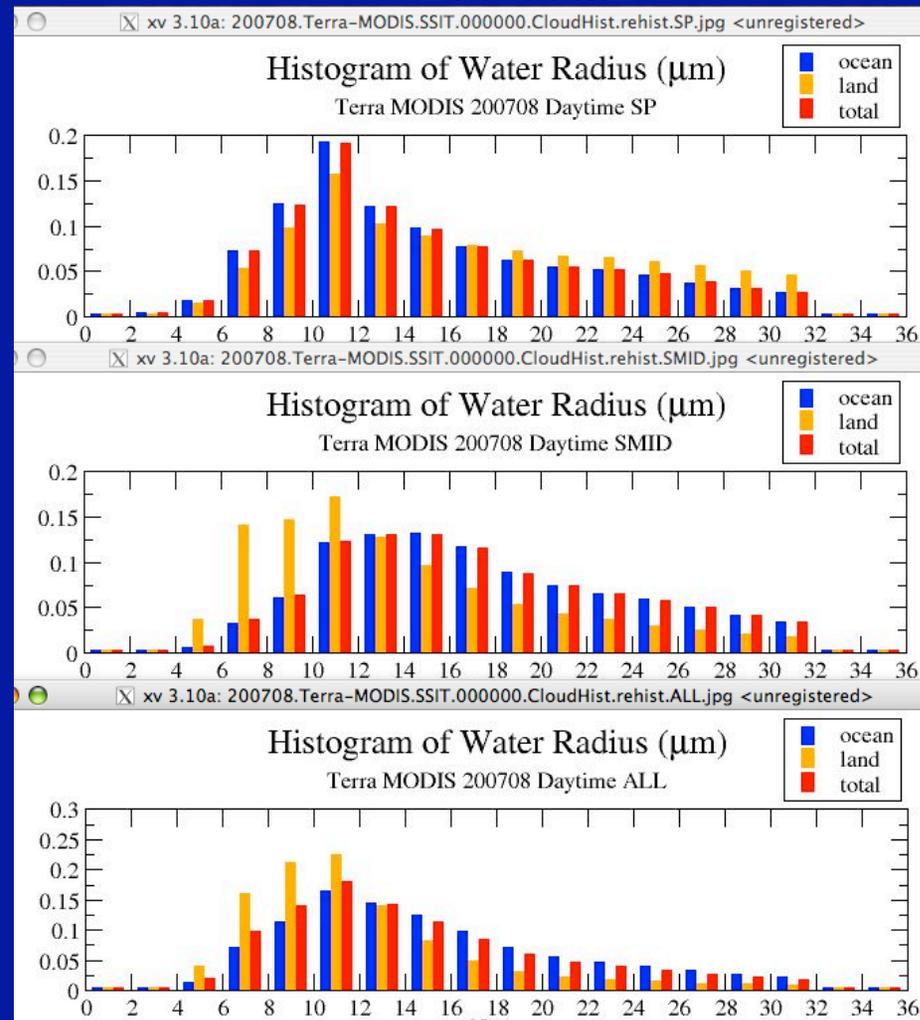
# Water Cloud Reff Frequencies, Terra, July 2008

## South pole to 20°S, All zones

Ed2



Ed3-beta2

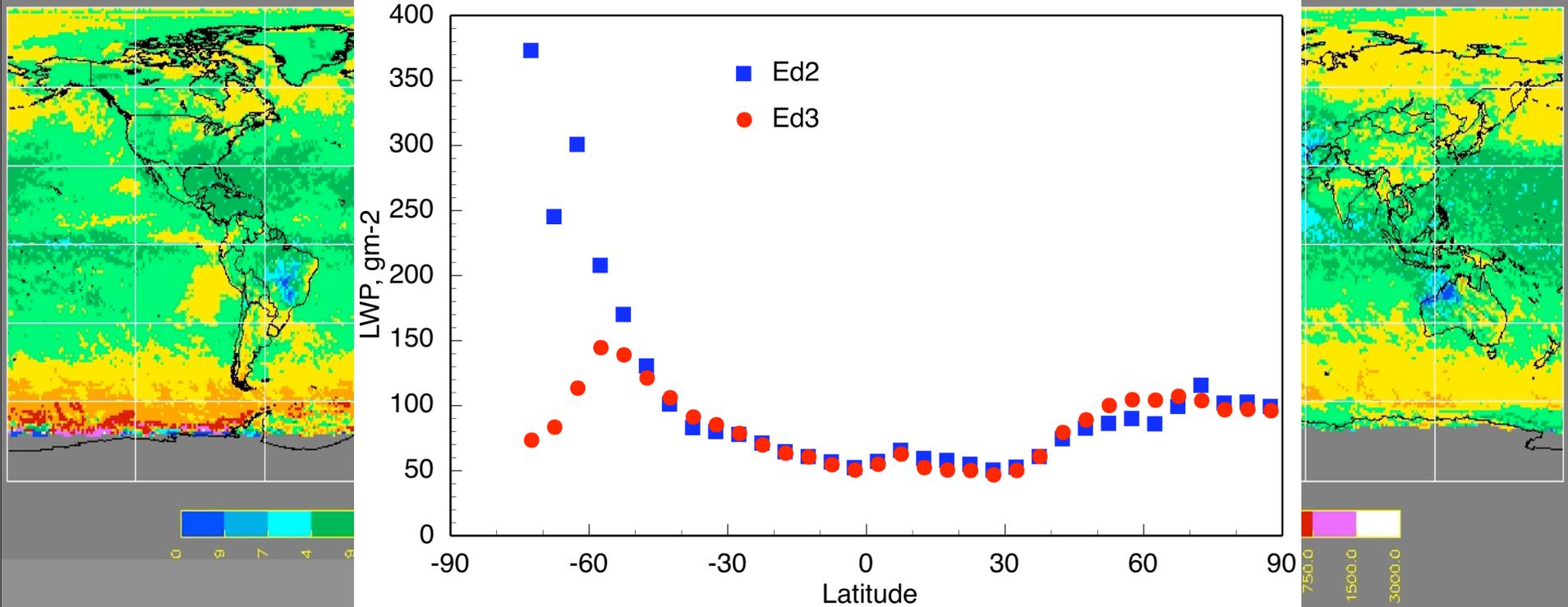


- larger Re more common in Ed3
- fewer Re < 8  $\mu\text{m}$  over deserts

# Liquid Water Path, Terra, July 2008

Ed2

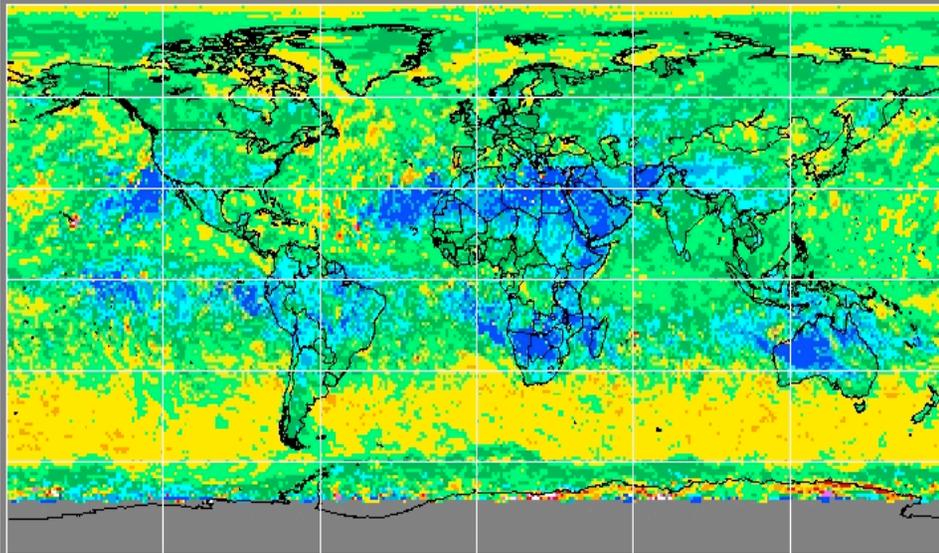
Ed3-beta2



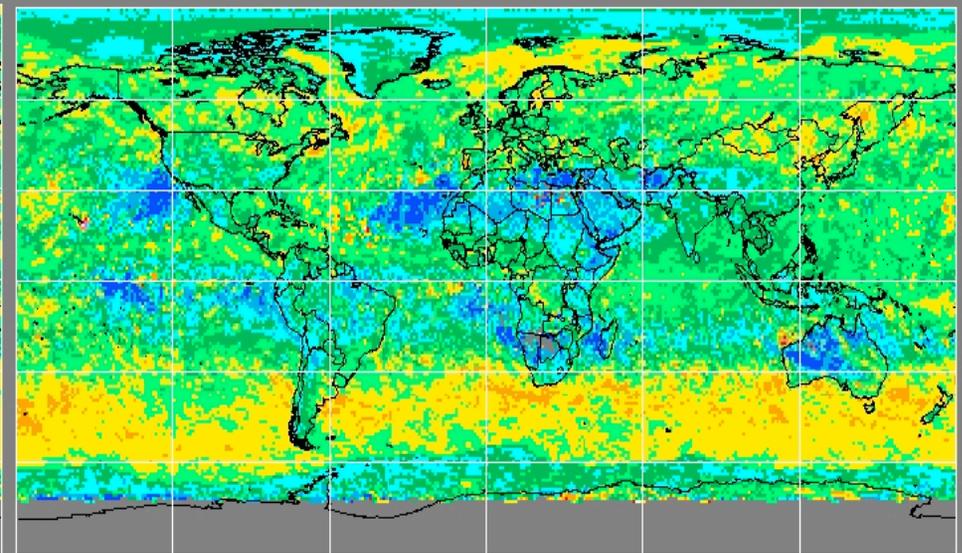
- LWP decreased from 177 to 100  $\text{gm}^{-2}$  in polar regions
- LWP dropped from 76.4 to 73.5  $\text{gm}^{-2}$  in non-polar regions
  - increased in upper Northern Midlats
  - decreased in upper Southern Midlats
- Much more realistic zonal variation than Ed2

# Effective Ice Crystal Diameter ( $\mu\text{m}$ ), Terra, July 2008

Ed2



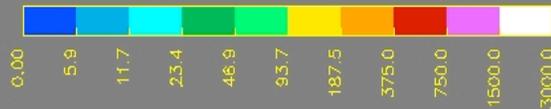
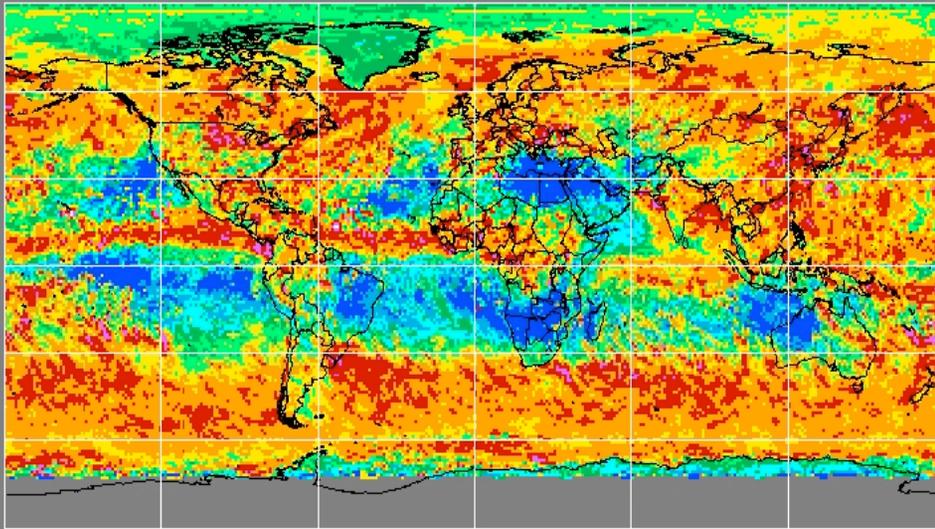
Ed3-beta2



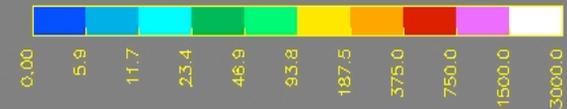
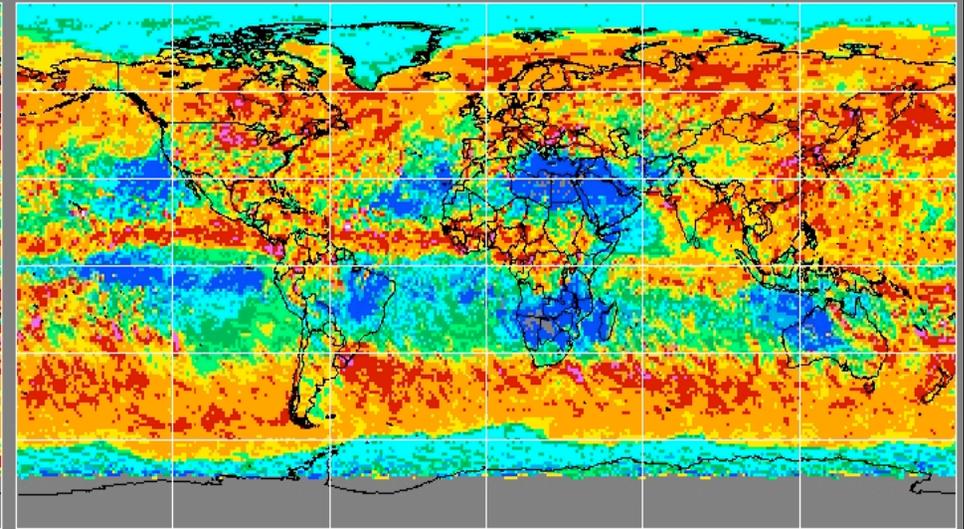
- De generally smaller in polar regions, 53.5  $\rightarrow$  49.8  $\mu\text{m}$
- De mostly larger in non-polar regions, 50.0  $\rightarrow$  50.6  $\mu\text{m}$
- Mostly a wash globally, 50.4  $\rightarrow$  50.5  $\mu\text{m}$

# Ice Water Path, Terra, July 2008

Ed2

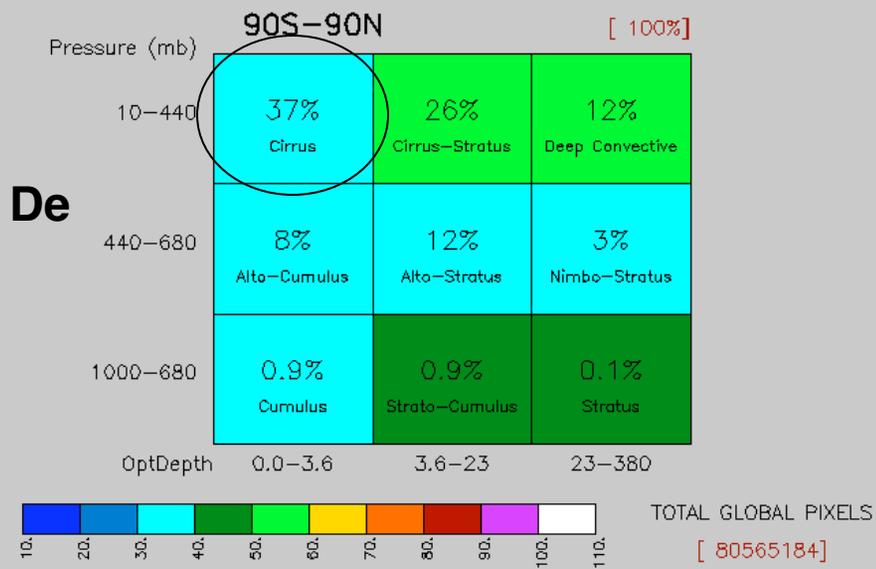


Ed3-beta2

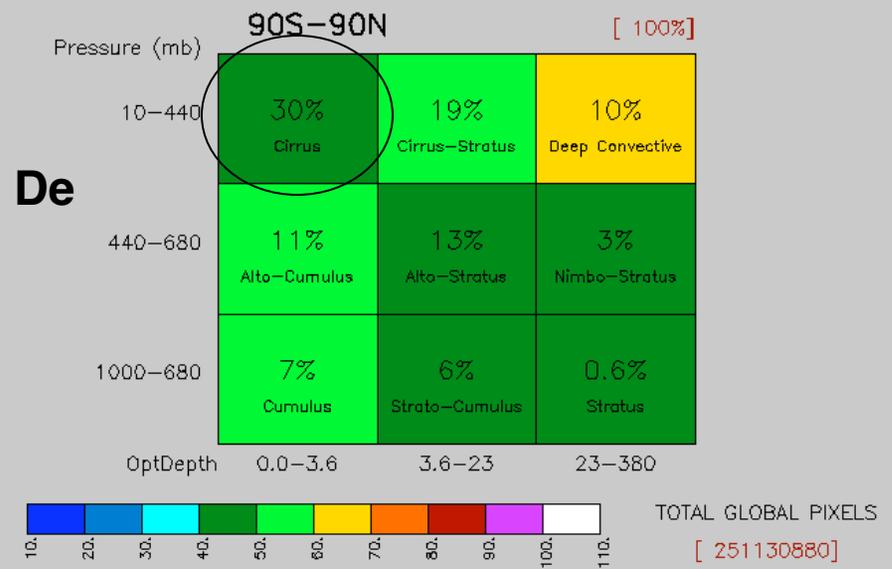


- IWP decreased from 199 to 145  $\text{gm}^{-2}$  in polar regions
- IWP dropped from 213 to 197  $\text{gm}^{-2}$  in non-polar regions
- Overall decrease of 10% relative to Ed2
  - drop in tau
  - addition of more thin cirrus

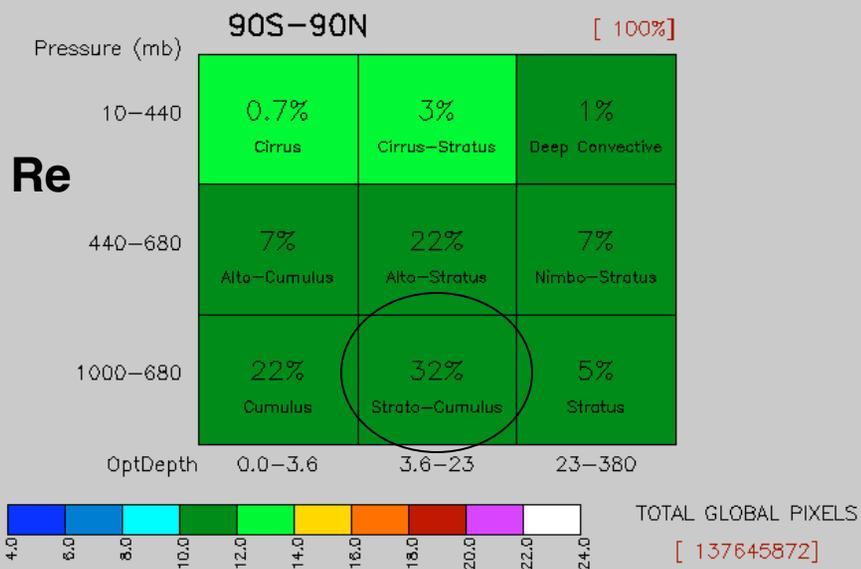
200708 ISCCP Global Averaging of PartSize  
**Day Time, Ice, Land**



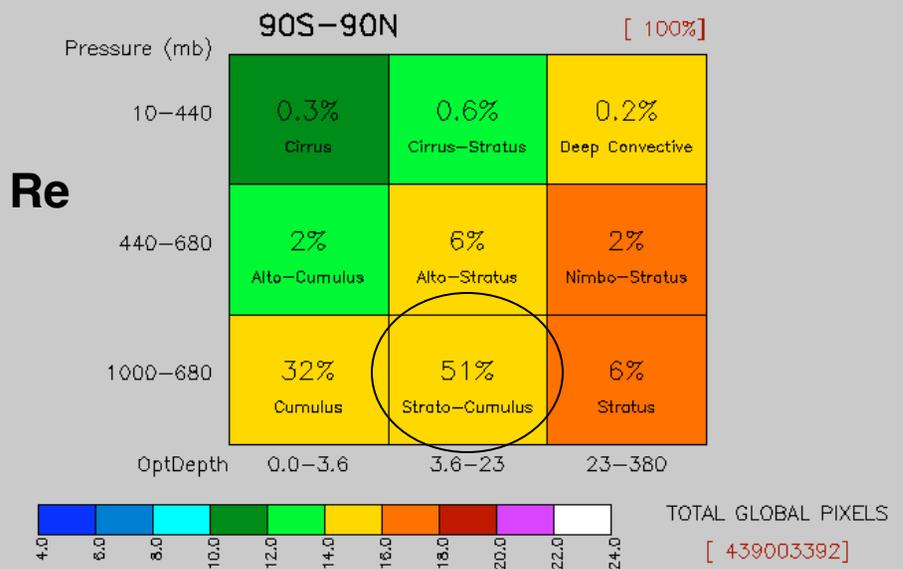
200708 ISCCP Global Averaging of PartSize  
**Day Time, Ice, Ocean**



**Day Time, Water, Land**



**Day Time, Water, Ocean**



## Multilayer Cloud Properties (New for Ed3-Beta2)



MultiLayer ID: BTD detection CO2 detection Pavlonis

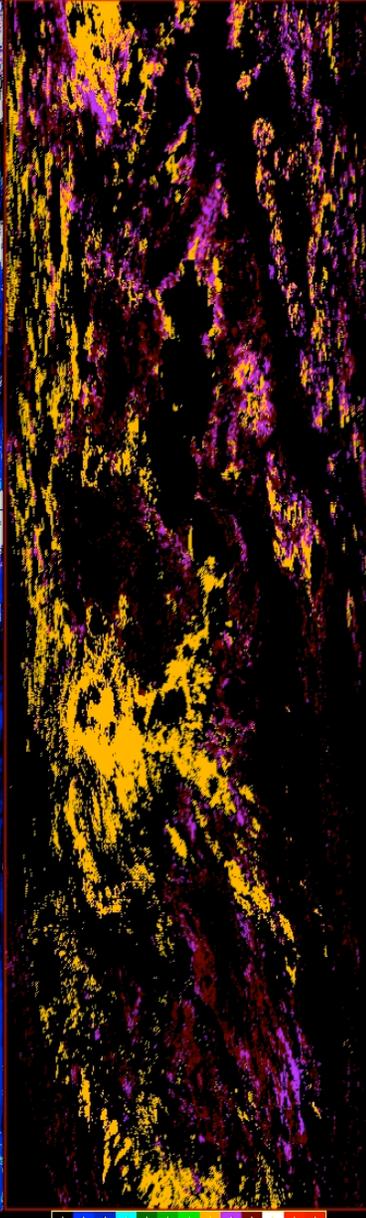
xv 3.10a: 2004071506.11176.Ed3B2D xv 3.10a: 2004071506.11176.Ed3B2D xv 3.10a: 2004071506.11176.Ed3B2D xv 3.10a: 2004071505.

BTD\_Multilayer\_Result  
[9.00 9.00] [0.00 8.00]

CO2\_Multilayer\_Detection  
[0.00 9.00] [0.00 8.00]

Pavlonis\_Multi\_Result  
[0.00 9.00] [0.00 8.00]

xv 3.10a: 2004071506.11176.Ed3Beta2.Aqua.g



Aqua 20040715  
06 H

- Multi:   
- Single Ice: 
- Single Water: 
- Conve. Clouds: 

Drop UnCrop AutoCrop About XV

MultiLayer:

Tau-Upper

Tau-Lower

Height-Upper

Height-Lower

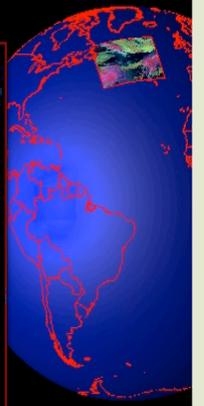
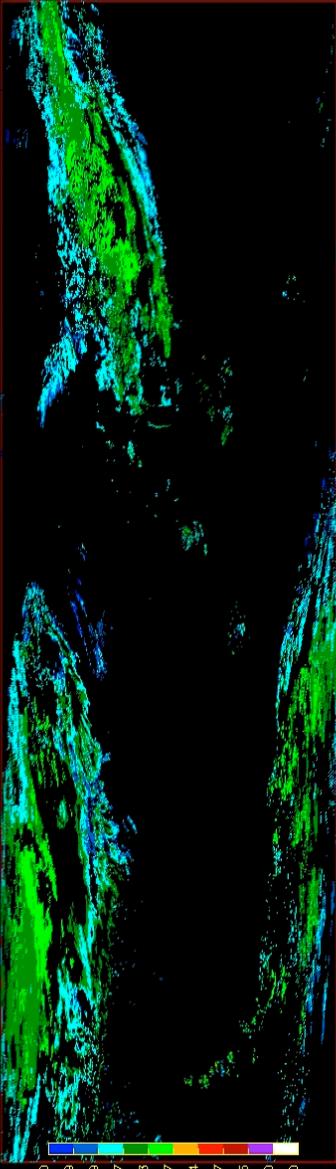
xv 3.10a: 2004071515.05080.Ed382D xv 3.10a: 2004071515.05080.Ed382D xv 3.10a: 2004071515.05080.Ed382D xv 3.10a: 2004071515.05080.Ed382D xv 3.10a: 2004071515.05080

CEM\_MultTau\_Up  
[3.72 14.14] [0.23 4.83]

CEM\_MultTau\_Lo  
[0.63 150.00] [0.63 150.00]

CEM\_MultTopHgt\_Up  
[3.72 14.14] [4.41 13.12]

CEM\_MultTopHgt\_Lo  
[0.63 150.00] [0.05 4.06]

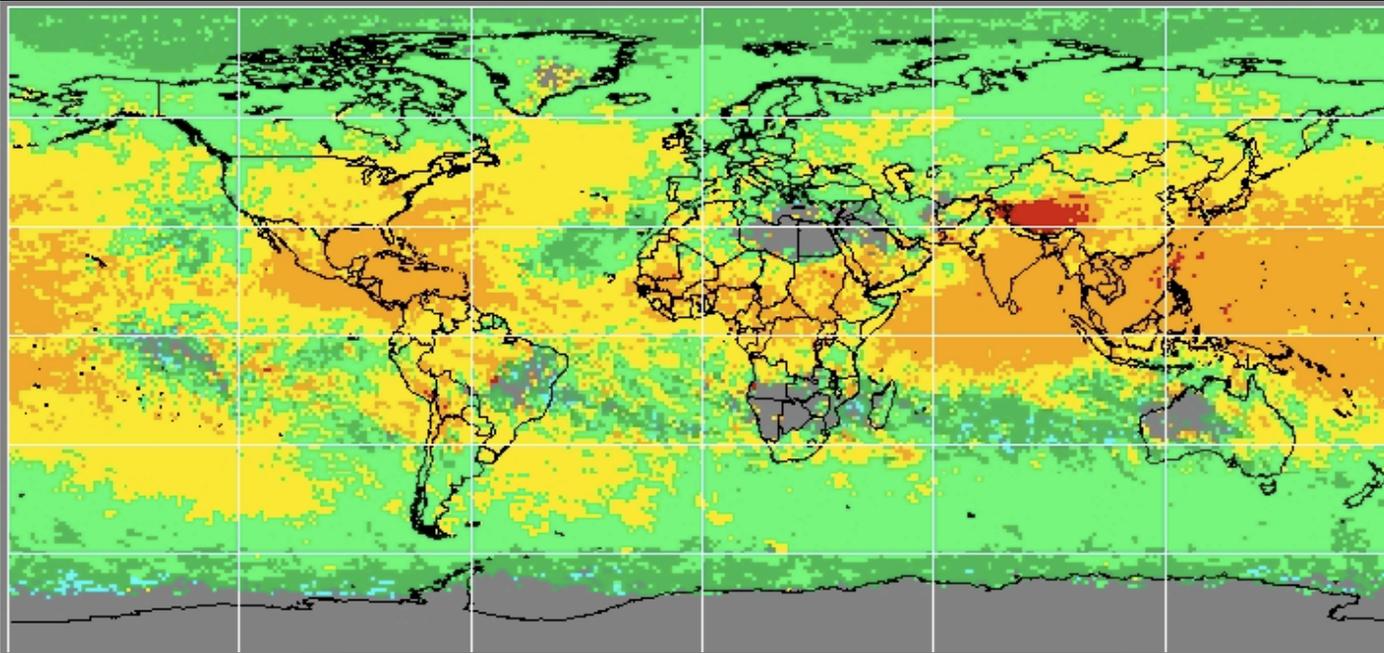


Aqua  
2004  
0715  
15 H

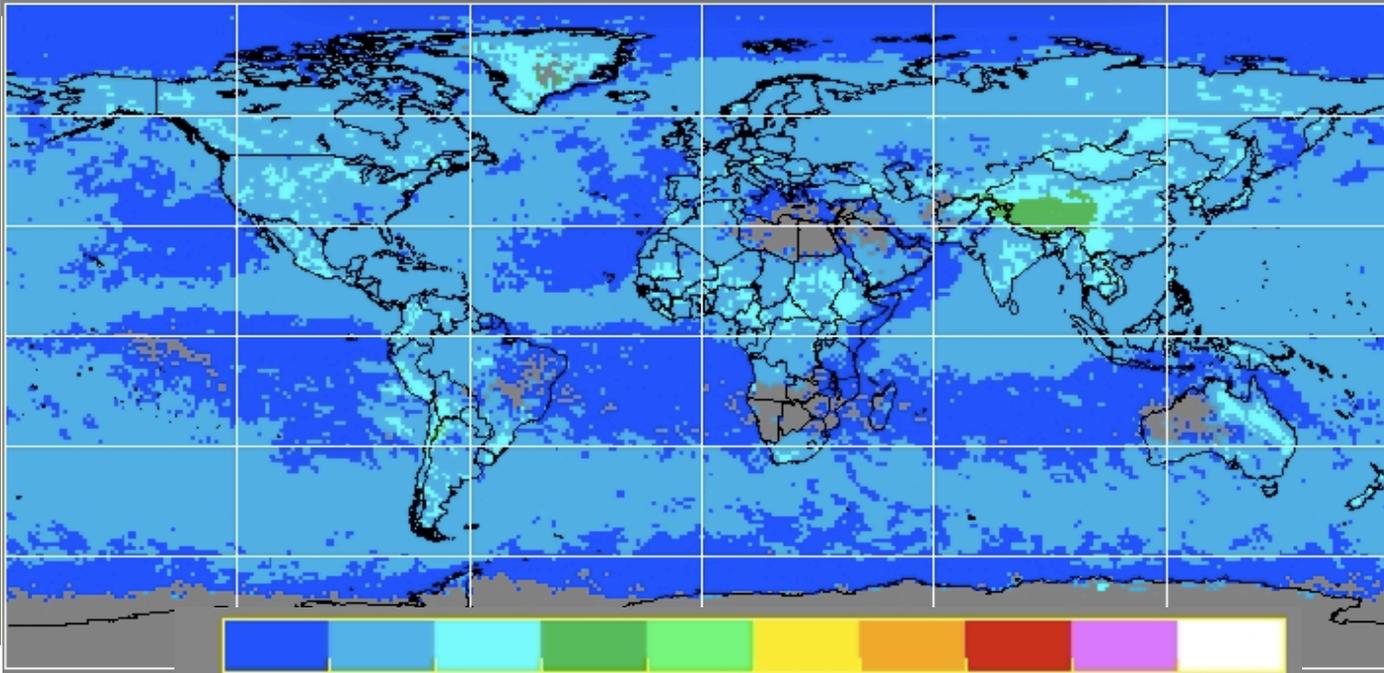


Terra 200708  
Day Time

**Multi Clouds  
Upper Layer Cloud  
Top Height (km)**



**Multi Clouds  
Lower Layer Cloud  
Top Height (km)**



MultiLayer:

Tau-Upper

Tau-Lower

De-Upper

Re-Lower

xv 3.10a: 2004071508.05080.Ed382D

xv 3.10a: 2004071508.05080.Ed382D

xv 3.10a: 2004071508.05080.Ed382D

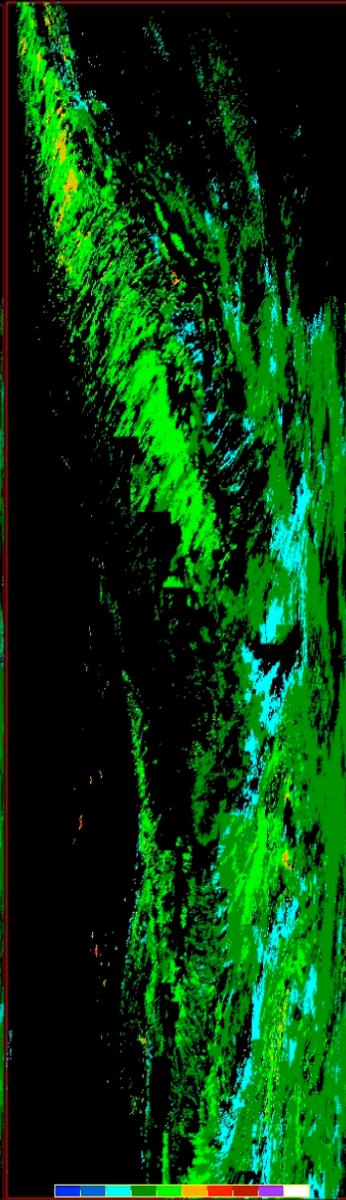
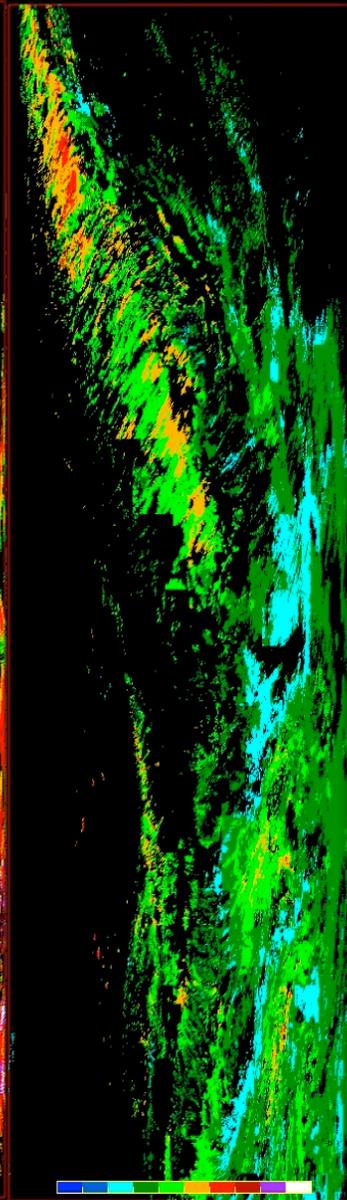
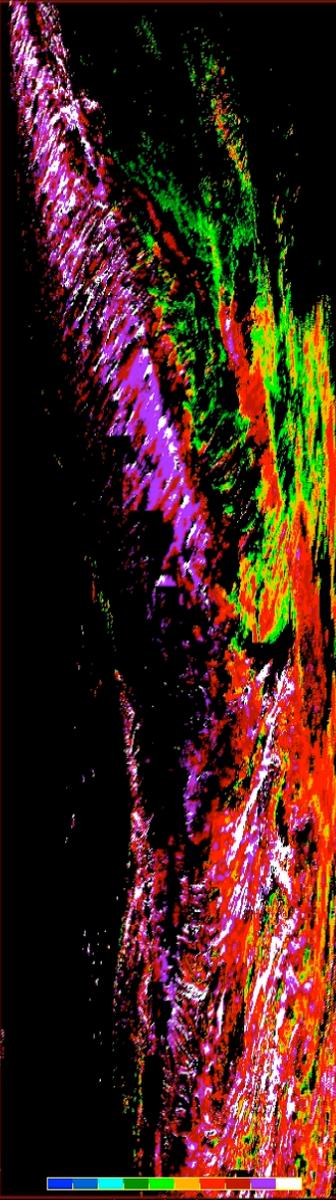
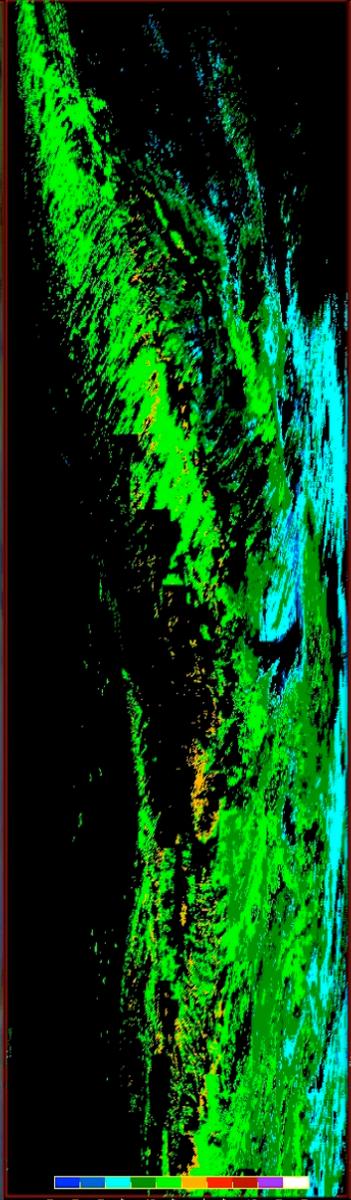
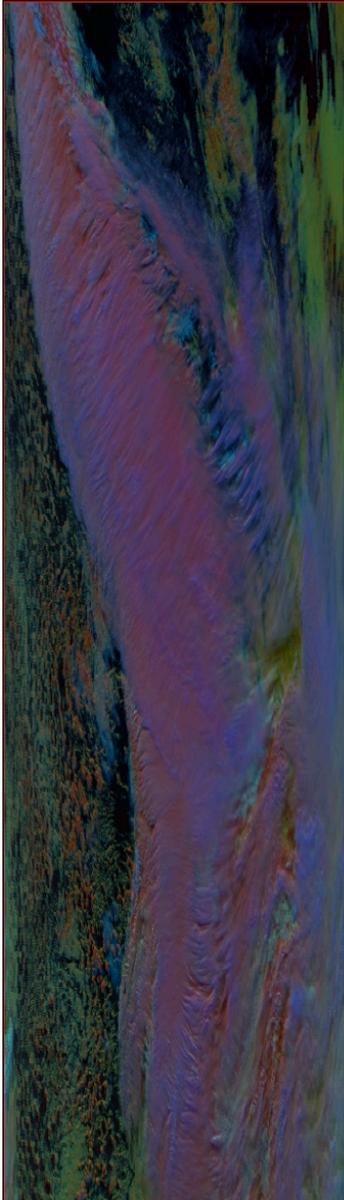
xv 3.10a: 2004071508.05080.Ed382D

CEM\_MultTau\_Up  
[3.67 13.61] [0.30 4.83]

CEM\_MultTau\_Lo  
[1.35 150.00] [1.35 150.00]

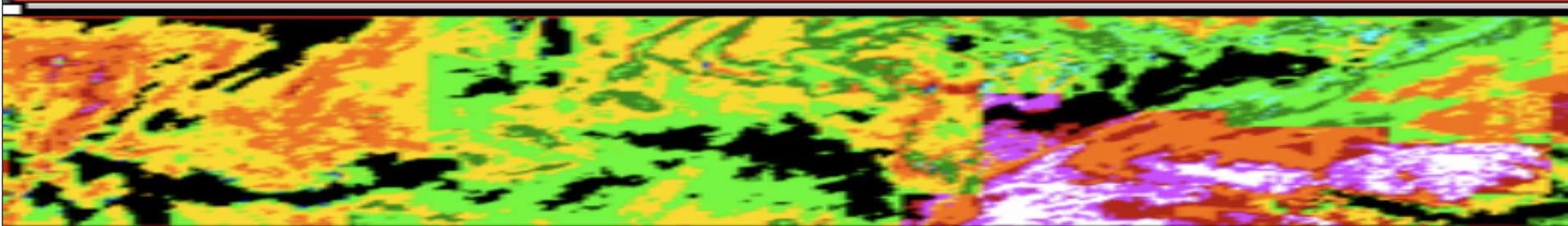
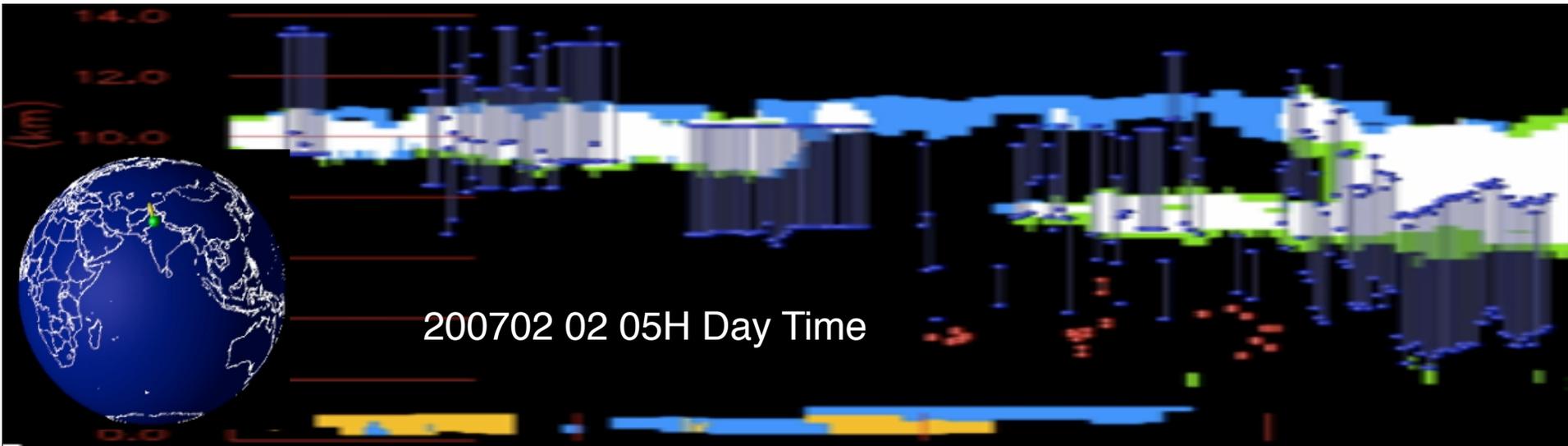
CEM\_MultSize\_Up  
[3.67 13.61] [35.50 97.69]

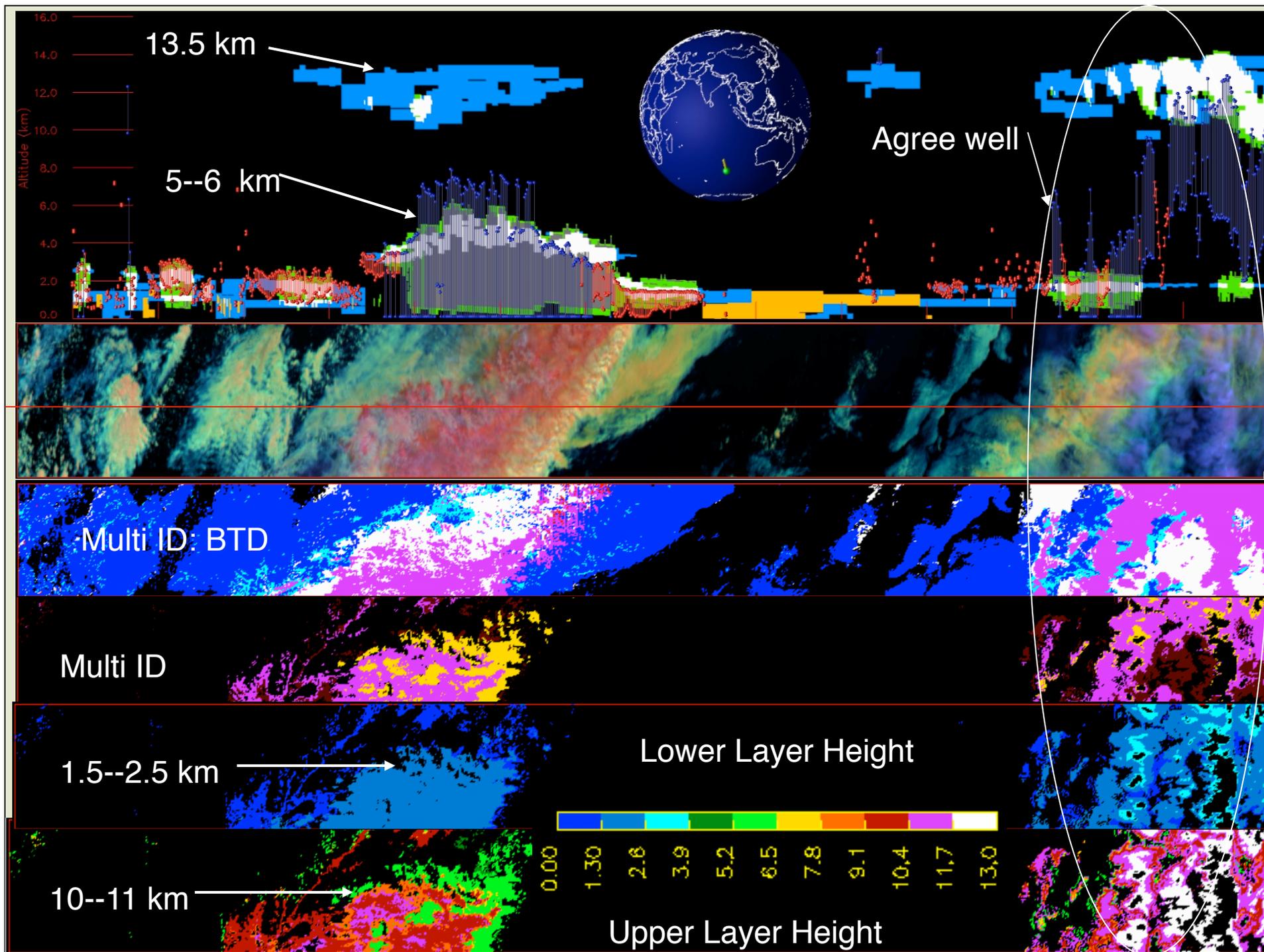
CEM\_MultSize\_Lo  
[1.35 150.00] [7.58 24.91]



Aqua  
2004  
0715  
08 H

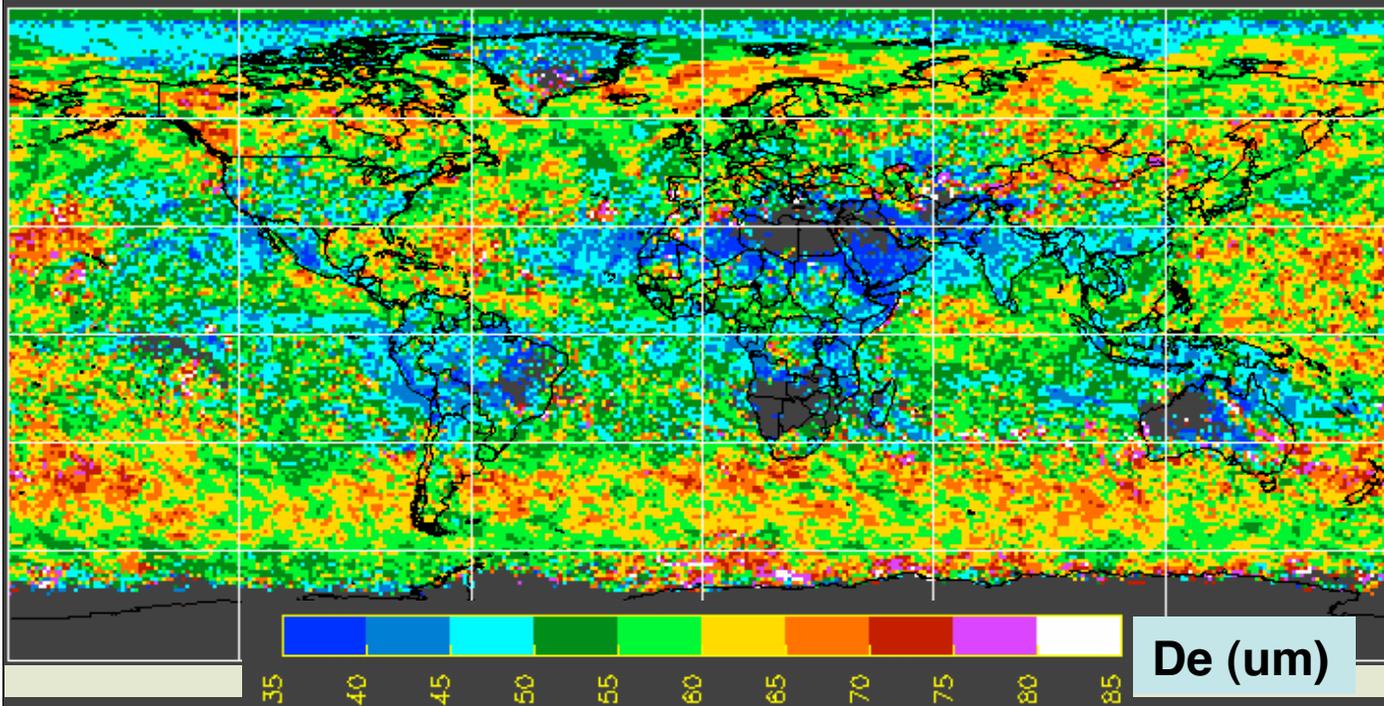




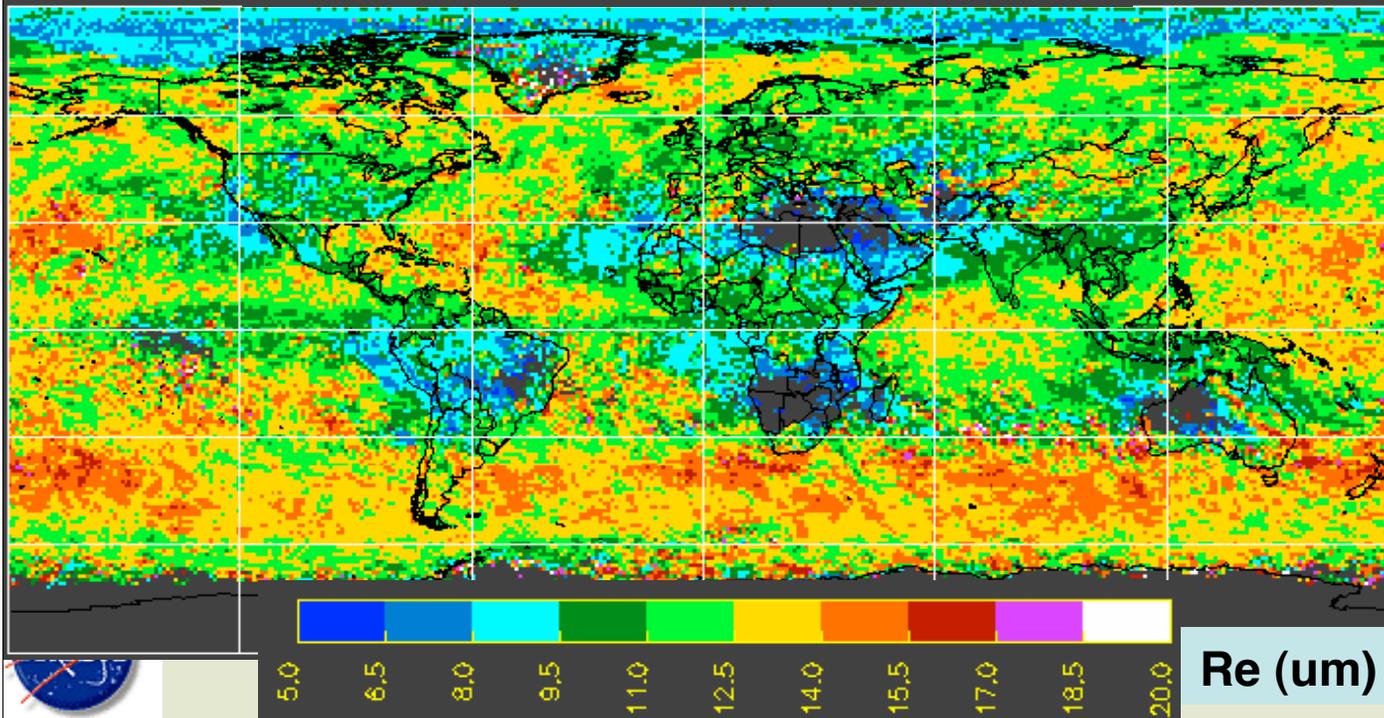


Terra 200708  
Day Time

**Multi Clouds  
Upper Layer Ice  
Cloud Diameter (um)**



**Multi Clouds  
Lower Layer Water  
Cloud Radius (um)**



## Future Work for Final Ed3

- False clouds in Antarctic
- Change De to Deg?
- Revise cloud thickness parameterizations
  - use CloudSat-based water cloud parameterization?
  - examine radar data from ARM sites?
  - use separate method over polar regions?
- Use of CO<sub>2</sub>
  - rough models?
  - do not apply cloud-top height correction for thin cirrus?
- Cloud-top heights
  - test for potential ML clouds first to prevent overcorrecting
  - what is source of strange overestimates?
  - use seasonal lapse rates?
- ML algorithm
  - ensure that all input is correct
  - use only two most certain categories? Decide when to perform retrieval
  - use only over non-snow sfcs?
- 2.13- $\mu$ m saturation
  - test use of 1.24- $\mu$ m channel
  - use IR data to determine thin from thick ice clouds

